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REPORT

ON

STEAM CARRIAGES,

BY A

SELECT COMMITTEE OF THE HOUSE OF COMMONS

OF

GREAT BRITAIN:

WITH THE

MINUTES OF EVIDENCE

AND

APPENDIX.

REPRINTED BY ORDER OF THE HOUSE OF REPRESENTATIVES.

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1832.

In the House of Representatives of the United States,

February 9, 1832.

On motion of Mr. Mercer,

Resolved, That the Report of a Select Committee of the House of Commons of Great Britain, bearing date October 12th, 1831, on the use of Steam Carriages on Common Roads, with the Minutes of Evidence, and Appendix attached thereto, be printed.

REPORT.

The Select Committee appointed to inquire into, and to report upon, the proportion of tolls which ought to be imposed upon coaches and other vehicles propelled by steam or gas, upon turnpike roads; and also, to inquire into, and to report upon, the rate of toll actually levied upon such coaches or other vehicles under any acts of Parliament now in force; and who were instructed to inquire generally into the present state and future prospects of land carriage by means of wheeled vehicles propelled by steam or gas on common roads; and to report upon the probable utility which the public may derive therefrom; and who were empowered to report the minutes of the evidence taken before them, to the House; have examined the matters referred to them, and agreed to the following report:

The committee proceeded, in the first instance, to inquire how far the science of propelling carriages on common roads by means of steam or mechanical power, had been carried into practical operation; and whether the result of the experiments already made had been sufficiently favorable to justify their recommending to the House that protection should be extended to this mode of conveyance, should the tolls imposed on steam carriages, by local acts of Parliament, be found prohibitory or excessive.

In the progress of their inquiry, they have extended their examination to the following points, on which the chief objections to this application of steam have been founded, viz. the insecurity of carriages so propelled, from the chance of explosion of the boiler, and the annoyance caused to travellers, on public roads, by the peculiar noise of the machinery, and by the escape of smoke and waste steam, which were supposed to be inseparable accompaniments.

It being also in charge to the committee, "to report upon the proportion of tolls which should be imposed upon steam carriages," they have examined several proprietors of those already in use, as to the effect produced on the surface of roads by the action of the propelling wheels.

As this was too important a branch of their inquiry to rest entirely on the evidence of individuals, whose personal interest might have biassed their opinions, the committee also examined several very scientific engineers, by whose observations, on the causes of the ordinary wear of roads, they have been greatly assisted.

The committee were directed also to report "on the probable utility which the public may derive from the use of steam carriages." On this point they have examined a member of the committee, well known for his intelligence and research on subjects connected with the interests of society, and they feel that they cannot fulfil this part of their instructions better than by merely referring the House to the evidence of Colonel Torrens.

These inquiries have led the committee to believe that the substitution of inanimate for animal power, in draught on common roads, is one of the most important improvements in the means of internal communication ever

introduced. Its practicability they consider to have been fully established; its general adoption will take place more or less rapidly, in proportion as the attention of scientific men shall be drawn, by public encouragement, to further improvement.

Many circumstances, however, must retard the general introduction of steam as a substitute for horse power on roads. One very formidable obstacle will arise from the prejudices which always beset a new invention, especially one which will at first appear detrimental to the interests of so many individuals. This difficulty can only be surmounted by a long course of successful, though probably unprofitable, experiment. The great expense of the engines must retard the progress of such experiments. The projectors will, for a long period, work with caution, fearing not only the expense incurred by failure, but also that too sudden an exposure of their success would attract the attention of rivals. It is difficult to exemplify to the House how small and apparently unimportant an adaptation of the parts of the machinery, or of the mode of generating or applying the steam, may be the cause of the most rapid success; yet he who, by a long course of experiment, shall have first reached this point, may be unable to conceal the improvement, and others will at once reap the benefit of it.

The committee are convinced, that the real merits of this invention are such, that it may be safely left to contend with these and similar difficulties; there are others, however, from which the legislature can alone relieve it. Tolls, to an amount which would utterly prohibit the introduction of steam carriages, have been imposed on some roads; on others, the trustees have adopted modes of apportioning the charge which would be found, if not absolutely prohibitory, at least to place such carriages in a very unfair position as compared with ordinary coaches.

Two causes may be assigned for the imposition of such excessive tolls upon steam carriages. The first, a determination on the part of the trustees, to obstruct, as much as possible, the use of steam as a propelling power; the second, and probably the more frequent, has been a misapprehension of their weight and effect on roads. Either cause appears to the committee a sufficient justification for their recommending to the House, that legislative protection should be extended to steam carriages with the least possible delay.

It appears from the evidence, that the first extensive trial of steam as an agent in draught on common roads, was that by Mr. Gurney, in 1829, who travelled from London to Bath and back in his steam carriage. He states, that although a part of the machinery which brings both the propelling wheels into action when the full power of the engine is required, was broken at the onset, yet that, on his return, he performed the last eighty-four miles, from Melksham to Cranford bridge, in ten hours, including stoppages. Mr. Gurney has given to the committee very full details of the form and power of his engine, which will be found in the evidence.

The committee have also examined Messrs. Summers & Ogle, Mr. Hancock, and Mr. Stone, whose steam carriages have been in daily use, for some months past on common roads. It is very satisfactory to find that, although the boilers of the several engines described, vary most materially in form, yet that each has been found fully to answer the expectation of its inventor. So well, in fact, have their experiments succeeded, that in each case where the proprietors have ceased to use them, it has only been for the purpose of constructing more perfect carriages, in order to engage more extensively in the business.

When we consider that these trials have been made under the most unfavorable circumstances—at great expense—in total uncertainty—without any of those guides which experience has given to other branches of engineering;—that those engaged in making them are persons looking solely to their own interest, and not theorists attempting the perfection of ingenious models;—when we find them convinced, after long experience, that they are introducing such a mode of conveyance as shall tempt the public, by its superior advantages, from the use of the admirable lines of coaches which have been generally established—it surely cannot be contended that the introduction of steam carriages on common roads is, as yet, an uncertain experiment, unworthy of legislative attention.

Besides the carriages already described, Mr. Gurney has been informed, that from "twenty to forty others are being built by different persons, all of which have been occasioned by his decided journey in 1829."

The committee have great pleasure in drawing the attention of the House to the evidence of Mr. Farey. His opinions are the more valuable from his uniting, in so great a degree, scientific knowledge to a practical acquaintance with the subject under consideration. He states that he has "no doubt whatever but that a steady perseverance in such trials will lead to the general adoption of steam carriages:" and again, "that what has been done proves to his satisfaction the practicability of impelling stage coaches by steam) on good common roads, in tolerably level parts of the country, without horses, at a speed of eight or ten miles per hour."

Much, of course, must remain to be done in improving their efficiency; yet Mr. Gurney states that he has kept up steadily the rate of twelve miles per hour; that "the extreme rate at which he has run is between twenty and thirty miles per hour."

Mr. Hancock "rekons that, with his carriage, he could keep up a speed of ten miles per hour, without injury to the machine."

Mr. Ogle states "that his experimental carriage went from London to Southampton, in some places, at a velocity of from thirty-two to thirty-five miles per hour."

"That they have ascended a hill rising one in six, at sixteen and a half miles per hour, and four miles of the London road at the rate of twenty-four miles and a half per hour, loaded with people."

"That his engine is capable of carrying three tons weight, in addition to its own."

Mr. Summers adds, "that they have travelled in the carriage at the rate of fifteen miles per hour, with nineteen persons on the carriage, up a hill one in twelve."

"That he has continued, for four hours and a half, to travel at the rate of thirty miles per hour."

"That he has found no difficulty of travelling over the worst and most hilly roads."

Mr. James Stone states that "thirty-six persons have been carried on one steam carriage."

"That the engine drew five times its own weight nearly, at the rate of from five to six miles per hour, partly up an inclination."

The several witnesses have estimated the probable saving of expense to the public, from the substitution of steam power for that of horses, at from one-half to two-thirds. Mr. Farey gives, as his opinion, "that steam

coaches will, very soon after their first establishment, be run for one-third of the cost of the present stage coaches."

Perhaps one of the principal advantages resulting from the use of steam, will be, that it may be employed as cheaply at a quick as at a slow rate; "this is one of the advantages over horse labor, which becomes more and more expensive as the speed is increased. There is every reason to expect that, in the end, the rate of travelling by steam will be much quicker than the utmost speed of travelling by horses; in short, the safety to travellers will become the limit to speed." In horse draught the opposite result takes place; "in all cases horses lose power of draught in a much greater proportion than they gain speed, and hence the work they do becomes more expensive as they go quicker." On this, and other points referred to in the report, the committee have great pleasure in drawing the attention of the House to the valuable evidences of Mr. Davies Gilbert.

Without increase of cost, then, we shall obtain a power which will insure a rapidity of internal communication far beyond the utmost speed of horses in draught; and although the performance of these carriages may not have hitherto attained this point, when once it has been established, that at equal speed we can use steam more cheaply in draught than horses, we may fairly anticipate that every day's increased experience in the management of the engines, will induce greater skill, greater confidence, and greater speed.

The cheapness of the conveyance will probably be for some time a secondary consideration. If at present it can be used as cheaply as horse power, the competition with the former modes of conveyance will first take place as to speed. When once the superiority of steam carriages shall have been fully established, competition will induce economy in the cost of working them. The evidence, however, of Mr. Macneil, showing the greater efficiency, with diminished expenditure of fuel, by locomotive engines on railways, convinces the committee that experience will soon teach a better construction of the engines, and a less costly mode of generating the requisite supply of steam.

Nor are the advantages of steam power confined to the greater velocity attained, or to its greater cheapness than horse draught. In the latter, danger is increased, in as large a proportion as expense, by greater speed. In steam power, on the contrary, "there is no danger of being run away with, and that of being overturned is greatly diminished. It is difficult to control four such horses as can draw a heavy carriage ten miles per hour, in case they are frightened or choose to run away; and for quick travelling they must be kept in that state of courage, that they are always inclined for running away, particularly down hills and at sharp turns of the road. In steam, however, there is little corresponding danger, being perfectly controllable, and capable of exerting its power in reverse in going down hills." Every witness examined has given the fullest and most satisfactory evidence of the perfect control which the conductor has over the movement of the carriage. With the slightest exertion it can be stopped or turned, under circumstances where horses would be totally unmanageable.

The committee have, throughout their examinations, been most anxious to ascertain whether the apprehension very commonly entertained, that an extensive use of these carriages on roads would be the cause of frequent accidents and continued annoyance to the public, were well founded.

The danger arising from the use of steam carriages, was stated to be two-

fold; that to which passengers are exposed from explosion of the boiler, and the breaking of the machinery, and the effect produced on horses by the noise and appearance of the engine.

Steam has been applied as a power in draught in two ways: in the one, both passengers and engine are placed on the same carriage; in the other, the engine carriage is merely used to draw the carriage in which the load is conveyed. In either case, the probability of danger from explosion has been rendered infinitely small, from the judicious construction of boiler which has been adopted.

These boilers expose a very considerable surface to the fire, and steam is generated with the greatest rapidity. From their peculiar form, the requisite supply of steam depends on its continued and rapid formation; no large and dangerous quantity can at any time be collected. Should the safety valve be stopped, and the supply of steam be kept up in a greater abundance than the engines require, explosion may take place, but the danger would be comparatively trifling, from the small quantity of steam which could act on any one portion of the boilers. As an engine, invented by Mr. Trevithick, has not been as yet applied to carriages, the committee can do no more than draw the attention of the House to the ingenuity of its contrivance. Should it in practice be found to answer his expectation, it will remove entirely all danger from explosion. In each of the carriages described to the committee, the boilers have been proved to a considerably greater pressure than they can ever have to sustain.

Mr. Farey considers that "the danger of explosion is less than the danger attendant on the use of horses in draught; that the danger in these boilers is less than in those employed on the railway, although there even, the instances of explosion have been very rare." The danger arising to passengers from the breaking of the machinery, need scarcely be taken into consideration. It is a mere question of delay, and can scarcely exceed in frequency the casualties which may occur with horses.

It has been frequently urged against these carriages, that wherever they shall be introduced, they must effectually prevent all other travelling on the road, as no horse will bear quietly the noise and smoke of the engine.

The committee believe that these statements are unfounded. Whatever noise may be complained of, arises from the present defective construction of the machinery, and will be corrected as the makers of such carriages gain greater experience. Admitting even that the present engines do work with some noise, the effect on horses has been greatly exaggerated. All the witnesses accustomed to travel in these carriages, even on the crowded roads adjacent to the Metropolis, have stated that horses are very seldom frightened in passing. Mr. Farey and Mr. Macneil have given even more favorable evidence in respect to the little annoyance they create.

No smoke need arise from such engines. Coke is usually burned in locomotive engines, on railways, to obviate this annoyance; and those steam carriages which have been hitherto established also burn it. Their liability to be indicted as nuisances will sufficiently check their using any offensive fuel.

There is no reason to fear that waste steam will cause much annoyance. In Mr. Hancock's engine it passes into the fire, and in other locomotive engines it is used in aid of the power, by creating a quicker draught and more rapid combustion of the fuel. In Mr. Trevithick's engine it will be returned into the boiler.

The committee not having received evidence that gas has been practically employed in propelling carriages on common roads, have not considered it expedient to inquire as to the progress made by several very scientific persons who are engaged in making experiments on gasses, with the view of procuring a still cheaper and more efficient power than steam.

The committee having satisfied themselves that steam has been successfully adopted as a substitute for horse power on roads, proceeded to examine whether tolls have been imposed on carriages thus propelled, so excessive as to require legislative interference, and also to consider the rate of tolls by which steam carriages should be brought to contribute, in fair proportion with other carriages, to the maintenance of the roads on which they may be used.

They have annexed a list of those local acts in which tolls have been been placed on steam, or mechanically propelled carriages.

Mr. Gurney has given the following specimens of the oppressive rates of tolls adopted in several of these acts: On the Liverpool and Prescot road, Mr. Gurney's carriage would be charged £2 8s. while a loaded stage coach would pay only 4s. On the Bathgate road the same carriage would be charged £1 7s. 1d., while a coach drawn by four horses would pay 5s. On the Ashburnham and Totness road Mr. Gurney would have to pay £2, while a coach drawn by four horses would be charged only 3s. On the Teignmouth and Dawlish roads the proportion is 12s. to 2s.

Such exorbitant tolls on steam carriages can only be justified on the following grounds:

First, because the number of passengers conveyed on, or by, a steam carriage will be so great as to diminish (at least the extent of the difference of the rate of toll) the total number of carriages used on the road; or, secondly, because steam carriages induce additional expense in the repairs of the road.

The committee see no reason to suppose that, for the present, the substitution of steam carriages, conveying a greater number of persons than common coaches, will take place to any very material extent; and, as to the second cause of increased charge, the trustees, in framing their tolls, have probably not minutely calculated the amount of injury to roads likely to arise from them.

The committee are of opinion that the only ground on which a fair claim to toll can be made on any public road, is to raise a fund which, with the strictest economy, shall be just sufficient, first, to repay the expense of its original formation; secondly, to maintain it in good and sufficient repair.

Although the committee anticipate that the time is not far distant when, in framing a scheme of toll for steam carriages, their general adoption, and the great number of passengers which will be conveyed on a small number of vehicles, will render it necessary not only to consider the amount of injury actually done to the road, but also the amount of debt which may have been incurred for its formation or maintenance; yet at present they feel justified by the limited number of such carriages, and by the great difficulties they will have to encounter, in recommending to the House, that, in adopting a system of toll, the proportion of "wear and tear" of roads by steam, as compared with other carriages, should alone be taken into consideration.

Unless an experiment were instituted on two roads, the one reserved solely for the use of steam coaches, the other for carriages drawn by horses, for the purpose of ascertaining accurately the relative wear of each, it would

be quite impossible to fix with certainty the proportion of tolls to which, on the same road, each class of vehicles should be liable. To approximate, however, as nearly as possible to the standard of relative wear, the committee have compared the weights of steam carriages with those of loaded vans and stage coaches. They have tried to ascertain the causes of the wear of roads; also the proportion of injury done by the feet of horses and the wheels of coaches; how far that injury is increased by increased velocity, and also in what degree the wear of roads by loaded carriages may be decreased by any particular form of wheel.

The committee would direct the attention of the House especially to the evidence of Mr. Macneil, whose observations on this branch of the subject, being founded on a long course of very accurate experiment, are peculiarly interesting and useful. He estimates that the feet of horses drawing a fast coach, are more injurious to the road than the wheels, in the proportion of three to one, nearly; that this proportion will increase with the velocity; that by increasing the breadth of the tires of the wheels, the injury done to roads by great weights may be counteracted. He considers that, on a good road, one ton may be safely carried on each inch of width of tire of the wheels.

Mr. M'Adam and Mr. Telford have given corresponding evidence as to the greater wear caused by horses' feet than by wheels of carriages.

Each of the above witnesses agrees, that, adding the weight of the horses to that of the coach, and comparing to the injury done to a road by a steam carriage of a weight equal to that of the coach and horses (the wheels being of a proper width of tire), the deterioration of the road will be much less by the steam carriage than by the coach and horses.

As to the injury to roads which is anticipated from the "slipping" of the wheels, it may safely be left to the proprietors to correct: the action of the wheel slipping involves a waste of power and an useless expenditure of fuel, which, for their own sakes, they will avoid.

Apprehension has also been entertained that, although the peculiar action of the wheels may not be injurious, yet that, from the great power which may be applied if the steam were worked at very high pressure, or if the size of the engine were increased, greater weight might be carried than the strength of the road could bear.

Undoubtedly, in proportion to the advance of the science, will be the increase of weight drawn by an engine with a given expenditure of fuel; but there are many practical difficulties to be surmounted before the weight so drawn can reach the point when it could be destructive of roads. There are no theoretical reasons against the extension of the size of the engines. The difficulties, according to Mr. Gurney, are of a practical nature, and only in the "difficulty of management of a large engine." In proportion as we augment the power of the engines, we must increase their strength, and consequently their weight; the greater weight will be a material diminution of their efficiency. To a certain extent the power may be increased in a greater ratio than the weight, but, with our limited knowledge of the application of steam, and with the present formation of the public roads, the point will be very soon attained, when the advantage of increased power will be counterbalanced by the difficulties attendant on the increased weight of the engines.

The weight of the steam carriages at present in use, varies from 53 to 80 cwt.; but it must be recollected that they are mere models; they were made with attention to strength only, to bear the uncertain strain to which they

would be exposed in the course of experiments, and a very considerable diminution of weight may be anticipated.

The weight drawn, at the rate of ten miles per hour, By Mr. Gurney's engine, has not, on any extent of road, exceded the weight of the drawing carriage; nor is it likely, with the difficulties to be encountered on the present lines of road, from their quality and the numerous ascents, that the weight drawn will be in excess of the strength of the roads. The immense quantity of spare power required to surmount the different degrees of resistance likely to occur, would render the engine too unmanageable. This will appear evident from the force of traction required to draw a wagon over the Holyhead and Shrewsbury road, which varied from 40 to upwards of 500 lbs.

In considering the effect on roads, we must not overlook one peculiarity in which they have a great advantage over other carriages. In coaches drawn by horses, the power being without the machine to be removed, it becomes an object of the greatest importance to give as much effect as possible to the power, by diminishing the resistance arising from the friction of the wheels upon the surface of the road. For this purpose, the proprietors of coaches and wagons have adopted every possible contrivance, so to reduce the tires of their wheels, that a very small portion of them may press on the road; in some coaches they are made circular in their cross section, so that the entire weight of the carriage presses on a mere point; should the materials be soft, such wheels cut their way into the road like a sharp instrument. The owners of wagons too have adopted a similar plan. Mr. Macneil states that the actual bearing part of the tire of apparently broad-wheel wagons, is reduced to three inches by the contrivance of one band of the tire projecting beyond the others.

With steam, on the contrary, a certain amount of adhesion to the roads is required to give effect to the action of the machinery, or the wheels would slip round and make no progress. It appears of little importance therefore, so far as relates to the engine, whether the requisite amount of friction be spread over a broad surface of tire, or be concentrated to a small point; but as the wheels, by being too narrow, would have a tendency to bury themselves in every soft or newly made road, and thus raise a perpetual resistance to their own progress, it actually becomes an advantage to adopt that form which is least injurious to the road. The proprietors, who have been examined on this point, seem to be quite indifferent as to the breadth of tire they may be required to use.

These considerations have convinced the committee, that the tolls enforced on steam carriages have, in general, far exceeded the rate which their injuriousness to roads, in comparison with other carriages, would warrant; they have found, however, considerable difficulty in framing a scale of tolls applicable to all roads, in lieu of those authorized by several local acts.

With this view, they have carefully examined the various modes of imposing toll either suggested by the witnesses, or already adopted.

They are as follows:

1. To place a toll proportioned to the weight of the carriage and load;
2. On the number of passengers;
3. On the horse-power of the engine;
4. On the number of wheels;
5. An unvarying toll.

Each of these plans seems liable to serious objections, which the committee beg to submit to the House.

No plan of toll has been more frequently recommended than that of a charge in proportion to the weight of the engine and load. As this is the most plausible, and (if it could be levied without other disadvantages) would probably be the fairest standard, the committee have considered it right to state, at some length, their reasons for not recommending its adoption.

If weight be taken as the standard, the toll must be a fixed charge, either upon the weight of the engine and carriage, without reference to the load; or upon an estimated average of the load carried; or a fluctuating charge, according to the weight, at the several periods of a journey.

The first would be at least free from the uncertainty of the other two, and therefore would be preferable; but what scale of charge per cwt. could the committee recommend as applicable to all roads? Their toll should vary according to every different rate of charge on carriages; besides, it would appear to the trustees very unjust to exclude the consideration of that which would be deemed the most material cause of the wear of their roads, viz: the load.

A fluctuating charge on weight would be most injurious to a carriage, which will mainly depend for success on its speed; constant altercations would take place between the toll collectors and proprietors; a minute calculation would be required at every turnpike gate; in fact, unless an accountant were placed at each, the committee cannot conceive how the proportions could be satisfactorily arranged, nor would there be any desire, on the part of the toll collector, to shorten the delay occasioned by these interruptions.

Mr. Gurney has delivered in a scale of tolls graduated according to weight and width of tire of the wheel. As this has been drawn up by a person interested in the success of steam carriages, it might have been expected to be more favorable to them. The committee, however, have not adopted it, because of the difficulties and interruptions which a fluctuating rate of toll would induce; besides, this scale purports to be intended for a road, where 3*d.* is charged for a horse drawing, and 1*d.* for a horse not drawing; the scale would be inapplicable therefore when the charge was 2*d.* and 1*d.*, 3*d.* and 1½*d.*, 4*d.* and 1*d.*, 4*d.* and 1½*d.*, 8*d.* and so on. Again, what standard of weight, in relation to horse coaches, could be adopted? The average weight of loaded coaches differs very much on different roads. It has been suggested, that a loaded coach, including the weight of four horses, would weigh on an average four tons; and that if 6*d.* per horse were chargeable to the coach, 6*d.* per ton should be placed on a steam carriage; this would be unjust, as vans, which frequently weigh upwards of six tons, would only pay 2*s.*, and a steam carriage would pay 3*s.* Even if the injury done to the road by each were equal, this would be an unfair toll; but it will appear more evidently unjust if the greater proportionate injury done by the feet of horses drawing, than by the propelling wheels, be taken into consideration.

The object of every steam coach proprietor will be to attain the greatest possible lightness of machinery and engine; because thereby he renders his power more efficient for the draught of the remunerating load. To place the toll on the weight of the engine would tend to induce him to decrease the strength of his boiler and machinery to an extent which might be dangerous to the passengers, and very detrimental to the success of steam travelling, as the public will easily be led to believe, that the accidents really occurring from injudicious legislation, were inseparable from the adoption of this power as an agent in propelling carriages.

The only fair plea for charging tolls on such carriages, in proportion to their weight, is to prevent a load being propelled or carried which would permanently injure the road; within this limit it would be as injudicious to interfere with their progressive efficiency, (which can only result from improvements of the machinery and the system of generating and applying steam) as it would be to tax carriages drawn by large and well-bred horses, more heavily than such as were drawn by horses in worse condition and of smaller size and power.

The roads at present have to sustain wagons, weighing, at times, with their horses, nearly ten tons; it is in evidence, that the breadth of wheels required by various acts of Parliament, is so easily evaded, that it affords no protection to the road. There appears to the committee no fair reason to suppose that steam carriages, approaching even to this weight, will be used on any turnpike road, at least for a very considerable period, during which the increase of weight will be gradual, and will give warning to the legislature when it should interfere.

To charge a toll according to the number of passengers conveyed, is scarcely less objectionable. If a fluctuating toll be intended, it would be as inadmissible as to propose a similar mode of charging for fast coaches, and would be open to all the cavil and interruptions to which a fluctuating toll on weight would be liable. If the toll were fixed according to the number of passengers the carriage were capable of conveying, it would imply the necessity of a license limiting the number of passengers, and cramping the progress of improvement of a machine, the capabilities of which can only be ascertained slowly and by continued experiment.

It must be also recollected that these carriages will probably have to travel for a long period without passengers, until by their punctuality and safety they shall have induced the public to venture in them. Nor is this probability weakened by the immense number of passengers who commenced using the locomotive carriages on the Manchester and Liverpool railway immediately after their introduction: these engines were established among a population accustomed to machinery and steam, and therefore not entertaining the same apprehensions of its danger which will require to be surmounted elsewhere.

The trustees of the Liverpool and Prescot road have already obtained the sanction of the legislature to charge the monstrous toll of 1*s.* 6*d.* per "horse-power," as if it were a national object to prevent the possibility of such engines being used. Besides, they have supplied no standard of their own conception of horse-power. Engineers have differed very much in their estimates of this power; there is not, therefore, much probability that the opposite interests of a steam coach proprietor and toll collector would lead to any agreement as to the meaning of the term. But suppose the legislature were to settle this point, and to arrange that a certain length of stroke and diameter of cylinder should represent a certain power, we still fail to ascertain that which alone it is essential to know, viz. the actual efficiency of the engine. Can we regulate the density of steam at which an engine of a given size should be worked? To be effectual, it would be also necessary to ascertain the quantity of water consumed, and even this check would be inadequate with an engine on Mr. Trevithick's principle. If the toll be left as at present on "horse power," it would be the obvious interest of the proprietor to work with the smallest nominal power, but to increase as much as possible the force of his steam, thereby increasing the probability of explosion.

Some trustees have placed the toll upon the number of wheels. The committee would object to this mode of charge, if only, because it interferes between the rival modes of steam travelling, and gives a bounty in favor of that in which the engine is placed on the same carriage with the passengers. The opposite plan of separating the engine from the carriage is that which probably the public will prefer, until the safety of the mode of conveyance shall have been fully ascertained.

There is still a more serious objection to this mode of charge: it tends to discourage the use of separate carriages; although it must be evident that, if a certain weight be carried, it will be much less injurious to the road when divided over eight wheels, than when carried on four only. On this point, the committee must again refer to Mr. Macneil's evidence. They cannot, therefore, recommend the House to adopt a scale of toll which shall increase in inverse proportion to the injury done to the road. It will be seen in Mr. M'Adam's evidence, that the toll on steam coaches imposed by the Metropolitan roads act, is liable to this objection.

Some of the local acts have placed an unvarying toll on steam carriages. This, if moderate, would be unobjectionable; but the committee could not propose any sum which would adapt itself to the necessary varieties of expense in keeping up different roads, by which the tolls on common carriages have been regulated. A fixed toll has, too, this disadvantage: that light experimental carriages, or such as are built solely for speed, would be liable to the same toll as steam carriages heavily laden.

The committee feel that, however strong their conviction may be of the comparatively small injury which properly constructed steam carriages will do to the roads, yet this conviction is founded more on theory, and perhaps what may be considered as interested evidence, than practical experience; they would therefore recommend that the House should not make, at present, any permanent regulations in favor of steam. The experience which will be gained in a very few years, will enable the legislature to form a more correct judgment of the effect of steam carriages on roads, than can be now made. They therefore recommend that the *tolls* imposed on steam carriages by local acts, where they shall be unfavorable to steam, shall be suspended during *three years;* and that, in lieu thereof, the trustees shall be permitted to charge toll according to the rate to which the committee have agreed.

The House will have perceived, in the former part of this report, that there are two modes of applying steam in lieu of horses in draught: one, where the engine and passengers are on the same carriage; the other, where the engine is placed on separate wheels, and is merely used to propel or draw the carriage. Although the difference of weight may be in favor of the former mode, yet, as on the latter it is divided over eight wheels instead of four, its small excess cannot justify a larger toll being imposed, as it will be found much less injurious to the roads. The committee therefore recommend that, in charging toll, the engine carriage and carriage drawn shall be considered but as one.

As it is the opinion of all the engineers examined, that the use of narrow wheels has been the great cause of the wear of roads, and that cylindrical wheels, of a certain width of tire, are not only the least injurious, but that, in some states of the road, they may be even beneficial, the committee recommend that the wheels of the engine carriage should be required to be cylindrical, and of not less than 3½ inches width of tire. No proprietor

of steam carriages has expressed the slightest fear of any inconvenience or loss from the use of such wheels. Beyond this, the committee would not recommend interference with the breadth of tire, or form of wheels: it should be left to the proprietors freely to select the breadth of tire they shall find most convenient in proportion to the weight carried.

The committee have divided steam carriages (intended for passengers) into two classes, to be subject to different rates of toll. The first, where the carriage is not plying for hire, or where, if plying for hire, it shall not be calculated for, or carry at any time, more than six passengers. The original cost of such machines, and the expense of working them, will sufficiently protect the roads from any great number of merely experimental carriages; and for the same reason they will not be of a weight or size likely to be injurious. A steam carriage only calculated to convey six passengers, will be solely used where great speed is required, and will be so light as to cause very little wear of the road, probably much less than many carriages drawn by the number of horses which the committee recommend as the standard of charge for this class. The toll, therefore, proposed to be placed on this class of steam carriages is that, which (on the several roads where they may be used) is charged on a carriage drawn by two horses.

In the second class, they have placed all other steam carriages, except those travelling at slow rates, for goods only: carriages of this class should pay the same toll as may be charged on a coach drawn by four horses. This may at first appear unjust from the supposed power of steam to draw almost unlimited weight. The committee have already enumerated the difficulties hitherto encountered in attempting to propel very heavy loads on turnpike roads. They are such as to discourage the expectation, that, within any short period of time, the system will have been so perfected as to give rise to inconvenience from this source: should any hereafter be found, it will then be sufficient to remedy the defect. Until a due proportion of the parts of the machinery shall have been ascertained, the makers of these carriages will vary but cautiously from the models at present in use: their object will be, for some time, the perfecting of them, rather than the uncertain experiment of increasing their size.

The committee do not anticipate that, for a considerable period, steam will be used as a propelling power on common roads for heavy wagons. It appears to have been the general opinion of the witnesses, that, in proportion as the velocity of travelling by steam on common roads is diminished, the advantages of steam over horse power are lost. The efficiency of horses in draught is rapidly diminished as their speed is increased; while, on the contrary, the weight which could be carried or propelled at any great velocity, by steam, could not be more cheaply conveyed were the speed decreased to that of the slowest wagon.

As speed, therefore, is the cause of greatly increased expense where horses are used, while with steam it is comparatively unimportant, it is probable that the latter will be chiefly resorted to when rapidity of conveyance is required. Mr. Gurney considers, that, under four miles per hour, horses can be used in draught more economically than steam. Should it, however, be deemed profitable to convey heavy goods by steam carriages, the committee recommend that there should be as little interference as possible with the number of carts employed; as the effect on the surface of roads would be infinitely more injurious if heavy loads were placed on a single cart, than if the same weight were divided over several. The committee recom-

mend, that where carriages, containing heavy goods alone, are propelled by steam, the weight of the load should be charged, without reference to the number of carts on which it may be carried.

As a horse is able to draw from 20 to 40 cwt. on common roads, they propose that each 20 cwt. of load conveyed in, or drawn by, a steam carriage, should be chargeable at the same rate of toll as one horse drawing a cart.

A charge on weight is not so objectionable where goods are conveyed at a slow rate, as when speed is alone required.

In conclusion, the committee submit the following summary of the evidence, given by the several witnesses, as to the progress made in the application of steam to the purposes of draught on common roads.

Sufficient evidence has been adduced to convince your committee—

1. That carriages can be propelled by steam on common roads at an average rate of ten miles per hour.
2. That at this rate they have conveyed upwards of fourteen passengers.
3. That their weight, including engine, fuel, water and attendants, may be under three tons.
4. That they can ascend and decend hills of considerable inclination with facility and safety.
5. That they are perfectly safe for passengers.
6. That they are not (or need not be, if properly constructed) nuisances to the public.
7. That they will become a speedier and cheaper mode of conveyance than carriages drawn by horses.
8. That as they admit of greater breadth of tire than other carriages, and as the roads are not acted on so injuriously as by the feet of horses in common draught, such carriages will cause less wear of roads than coaches drawn by horses.
9. That rates of toll have been imposed on steam carriages, which would prohibit their being used on several lines of road, were such charges permitted to remain unaltered.

MINUTES OF EVIDENCE.

Mercurii, 3° *die Augusti*, 1831.

Mr. *Goldsworthy Gurney* called in, and examined.

Are you the proprietor of a steam carriage used on public roads? Not the proprietor; I am the patentee.

On what roads have you commenced running such carriages? I have commenced on several roads. The first road I commenced was Edgeware, then Stanmore; I ran there for a short time only; principally experimentally; then to Barnet, to Edgeware, to Finchley, and other places. I also ran a carriage on my own account to Bath and back; that was onlyone journey;

an experimental journey. Since that they have been running as public stages, principally between Gloucester and Cheltenham.

For what period? Since February last. They were stopped about three weeks, in consequence of an accident to one of the axle-trees; they were to begin again about this time.

Have you been yourself on these carriages while they have been running? Yes; in the first instance, I almost always accompanied the carriage.

State in detail the progress which you have made in bringing these carriages to their present improved state? I must beg to have reference to the drawings. [*The witness produced the drawings, Nos.* 1, 2, 3, 4, 5, *and* 6.] This first drawing, No. 1, was the first experiment I made connected with the subject, in which I conceived I had removed the difficulty of driving steam carriages on common roads, by inventing a light and powerful boiler, of which this is a representation. The application of that boiler will be seen in No. 2. The boiler itself is not represented on the carriage in this drawing, but simply the engine, and the modes of propelling the carriage. This was in the year 1825. It was then a very prevalent opinion that the bite or friction of the power to the ground was not sufficient to propel the carriage along a common road, particularly up hill; it was thought that the wheel would turn round, and the carriage not proceed. With that view, the apparatus shown in this figure, No. 2, which I call feet or propellers, were proposed to be used; the mode of action I presume will be seen from the drawing. I soon found by experience, in numerous experiments not connected with the drawing, that the propellers were rarely or never wanted; and I then applied the power immediately to the two hind wheels, through a crank, in the common mode of a steamboat, the propellers being also fixed, but travelling slower than the wheels, were brought into action if the wheels slipped, which it was thought would be the case in difficult situations. This carriage went up Highgate hill in 1826, and to Edgeware, also to Stanmore, and went up Stanmore hill, and Brockley hill, near Stanmore, and against all those hills the wheels never turned, and the legs never came into action. This is No. 3. After these experiments, the legs or propellers were entirely removed, and from further experiment it was found, by a peculiar application of the steam, (namely, by "wire drawing,") that the bite of one of the hind wheels was sufficient for all common purposes. If the steam was let on suddenly, the wheel would turn round, and the carriage not go forward; but when wire-drawn, one wheel was found sufficient. By this arrangement, also, the carriage was guided more accurately and more easily. The second wheel was applied by uniting it with the crank at any time, if one was found insufficient.

In general, were the wheels connected together, or had they an independent motion? Always one was attached to the axle; they had no independent motion; this will be seen by reference to No. 5 on the arm or carrier of the wheel (which is a part of the axle,) and can be attached to the wheel at pleasure by a bolt, making the wheel also in that case part of the axle. This carriage, I should observe, ran to Barnet, snd went up all the hills to Barnet, in 1827, with one wheel only attached to the axle, and was run for about eighteen months experimentally in the neighborhood of London. From these experiments showing that one wheel was sufficient to propel the carriage, and the carriage being at the same time reduced two-thirds in weight, it was thought desirable to draw another carriage, instead of to carry on the same; that will be seen in No. 5. This carriage went to Bath, and over all

the hills between Cranford bridge and Bath, and returned with only one wheel attached to the axle; the other carrier, by means of attachment, having broken in the first onset, and not having been repaired until after its return; the carriage was also injured slightly at Melksham, in consequence of a riot there. We waited about two days at Bath to get this injury repaired, and returned from Melksham to Cranford bridge in ten hours, a distance of eighty-four miles, including stoppages. I have come now almost to the practical application of it. This is a drawing of the carriages we are now now building (No. 6.)

Have you made any alteration in the formation of the boilers since 1825? We have altered and changed in the mechanism only; the principle has been invariably adhered to; the present carriage is deprived of its chimney, and a variety of other disagreeables about the carriage.

Has your principle, with respect to all, remained the same? Precisely the same.

How far have you improved the formation of your working carriage as to weight? The weight was a principal objection to the practical application of the carriage. The first carriage of a given power weighed four tons; this was objectionable on account of its weight, which was severely felt in consequence of its effect on the roads. I thought it would injure the roads, which injury would produce a toll that would perhaps injure the economy of it: No. 3, weighed four tons; No. 4, weighed three tons, with the same power; No. 5, two tons, with the same power; the present carriages building will not weigh more than 35 cwt. with the same power.

What does the carriage which runs between Gloucester and Cheltenham weigh? By a letter from the magistrate, now produced, it is stated to weigh nearly three tons; it ought to weigh only 45 cwt.; if it weighs three tons, there is extra weight, of which I know nothing. This which I produce a sketch of, marked No. 6, weighs 35 cwt. and it has the same power. Those carriages at Gloucester were built principally under the superintendence of another person.

When you state the weight of 35 cwt. you mean the weight of the travelling carriage alone, without the weight of the passengers, or the weight of fuel or water? Yes, just so; I think it is possible to reduce the weight considerably as improvements go on. I have a carriage now building which I do not expect will weigh above five cwt., which I expected to do the work of about one horse, and carry two or three people; speed is a particular object, and it is not intended to carry any thing more than light parcels.

Into what stages would you divide your journeys most conveniently? I think about seven miles.

What weight of fuel and water would you lay in for such a stage? The fuel and water will be in proportion to the size and power of the carriage.

For a machine, weighing 35 cwt. marked by you No. 6, what weight of fuel and water would you require? Three bushels and a half of coke is the quantity we take to supply this distance, and the first charge two bushels; the first charge always remaining, it decreases of course down to the first charge, and, taking the mean, it will be 3¾. The weight of water at present I think is about 10 gallons a mile which is consumed, that would be 70 gallons, a gallon weighing about 10 lbs. making 700 lbs.; the mean of this will give the quantity. If the roads are good it does not take so much, we can do with almost half the quantity; if the roads are bad we must take the whole quantity, and the mean will be 350 lbs.

Will you state the progressive alterations you have made in the diameter of your wheel, and the breadth of the tire? The diameter of the wheel has generally been the same, about five feet.

What difference is there between the fore and hind wheels? About a foot in diameter difference; about the proportion of an ordinary carriage.

The power is attached to the hind wheels? To the hind wheels only.

Do the wheels follow in the same track? That is a matter of option.

The committee understand that they do not in that which travels between Cheltenham and Gloucester? Perhaps that is the case there; it is a matter of convenience in some experiments. I have built them with three wheels only, one wheel in front, and in some, as in No. 3, with six wheels; my present carriage has only four.

Do the hind wheels of your present carriage follow in the same track with the fore wheels? Yes; those carriages now building will do so; the hind wheels will be nearer to each other than in many others.

What diameter do you propose to make the propelling wheels of your new carriage? I propose to have them about five feet. I would observe, that by taking a wheel of five feet diameter off the axle, and putting on one of two feet six, the engine would be multiplied double in its power, and lose of course one half in speed. In some cases it may be desirable to do so if the carriages are used for general purposes; for speed or dragging of heavy weights alternately, larger or smaller wheels may be put to meet circumstances as they occur.

From the experiments you have made, with a view to proportion the diameter of the wheels with the weight to be drawn and the velocity required, what diameter of propelling wheel do you think will be generally used? Five feet; the piston of the engine should not travel more than two miles and a half per hour; therefore we may multiply from this rate to any speed we please.

What is the breadth of the tire of your present wheel? None less than two inches; but in late experiments we found a wide tire more desirable than a narrow one, and we have increased it to about three inches and a half in width; we found that there is no increase of power necessary with a wide wheel, but I think, on the contrary, rather less. We have not been able to decide positively the true variation in power, but the difference is so slight, that it is not perceptible.

What is the ordinary width of the tire of wheels of coaches? I think about two inches; in a private carriage rather under two, and in stage coaches over two inches.

Of how many horse power is your ordinary travelling engine? Twelve nominal steam engine horse-power; to work eight hours it takes the common stage coach 32 horses; an engine propelling the same weight for eight hours should be considered a 32 horse power, according to the rule laid down by engineers, but this is not true as to locomotive engines.

Taking your latest improvement, to what number of draught horses would it be equivalent? I think about 10 cwt. will do the work of a horse on the road; 35 cwt. will be about 3½ horses' work always.

You mean that it will displace about three horses and a half at a time on the road? Yes, in each stage it will displace 3½ or 4 horses, and about 30 horses in the eight hours.

Is that in practice, or in idea? Practice.

Is the chief weight supported on springs? The whole is on springs.

What is the weight of an ordinary stage-coach? About 24 cwt.; I think from 18 to 24.

How many persons will that take? I think about 18.

What would be the weight of your engine carriage sufficiently powerful to draw a carriage containing 18 persons? The weight of the propelling carriage would be about the weight of four horses; the weight of the carriage drawn would be precisely that of a carriage drawn by horses, and I find the weight of a horse to average about 10 cwt.; therefore, taking four horses at 10 cwt. the four horses would be two tons, which is somewhere about the weight of my carriage; to do the same work, some horses weigh as much as 16 cwt some considerably less than 10 cwt.

Have you examined the effect on the roads of the propelling wheels of your carriage? As far as I am enabled to judge, I should say that they did no more injury than any other carriage of the same weight; I mean the carriage itself, weight for weight. I have taken the loss of iron from the tires of the wheels, and compared it with that of the loss from other carriages running the same number of miles, and I found the loss the same nearly.

Do you find that the wheel never slides in the turn? If it does, it is either imperfect or the fault of the engineer; if the steam is wire-drawn (using the technical term) it never does so; if the steam is laid on suddenly on the engines, it acts like a percussion, and affects the wheels as if struck with a hammer. The carriage, of course, would not be propelled in such case.

Practically, as far as you have seen in the operations of these carriages, does the wheel slide in that way frequently? It may sometimes at starting for an instant, but never on the road unless it is over-weighted; I mean, if it has an over-weight attached to it.

Is there much smoke created by your carriage? There is no smoke unless any smoky matter gets accidentally into the fire, the fuel being coke; of course there will be smoke if there are coals.

Are you frequently obliged to let off steam? Yes, but not openly; the steam is allowed to escape from the safety-valve into a chamber peculiarly constructed, which prevents any nuisance from it.

There is no annoyance either from smoke or steam? There is no annoyance either from smoke or steam, when the engine is perfect.

Have you found that horses are more liable to be frightened by passing your carriages, than passing other carriages? As far as my own observation goes, I should say about the same. I have travelled with a carriage, I think, five years, more or less, every week. I have been very frequently in the public streets of London with the steam carriage, and the roads round London, and also in the private and public roads in the country; I have certainly seen horses shy often, but never saw a horse make a dead stand.

Is there a very peculiar noise attending the motion of your engine carriage? The noise of wire-drawing, &c. is at the will of the engineer; if the carriage should make a noise, he has the means of stopping the noise; but there ought not to be any disagreeable noise.

Must not the noise proceed from the imperfection of the works? Yes, and that only.

Do you attribute the startling of horses to the peculiar noise of the engine, or to its unusual appearance? I think it must be from its unusual appearance. It appears from an observation on the carriages at Cheltenham, made in this committee, to have been more troublesome than any where else. Those carriages were made with curtains, to inclose persons who might ride

in them, and the carriage altogether rather more *outré* in its appearance; from the flapping of those curtains, or some circumstances of that kind, the horses have been startled, or accidents have occurred there.

Are you aware that there is an imperfection in the carriage at Cheltenham, which is stated to occasion noise? I have not seen much of these carriages; I was never at Cheltenham but twice or thrice, and then but for a short time.

What have you found to be the effect of the wheels on a very rough road full of ruts? If you start the carriage from a rut, it takes more power; but when the carriage is in motion, the momentum takes it over all the inequalities with the usual force.

Do you find that when the propelling wheel gets into a rut, the first power it exerts is in sliding? Frequently; and sometimes it will be necessary to attach the two wheels, for one wheel will not be sufficient to get it out of that difficulty The engineer, in such case, attaches a second wheel by the bolt, and I have never known a situation yet, in which a carriage with both wheels attached will not get out. I have seen it in a clay pit eight inches deep propel itself through, having sunk through the upper surface of gravel in a yard.

When you attach the second wheel, is the increased power owing to the more favorable situation of the cranks? The power of the engine remains the same, but the application of it is doubled by friction.

Suppose that both wheels were in the rut? I have seen both wheels in a rut. In the case I have just spoken of they were both in a rut; in a different state of weather, the effect, hold or bite on the wheels is very different; if the state of the road is between half wet and half dry, it is more apt to slide; and, in some instances, with a heavy weight attached, we are obliged to go with both wheels locked, when the same weight would have been taken by one wheel only in very wet or dry weather.

Is it only in starting that that difficulty occurs? Only in starting on a level or slight incline; but up hills we have sometimes been obliged to attach both wheels; the bite only from the one wheel being not sufficient to propel a load behind it.

What is the operation of the propelling wheel when it meets with the obstruction of a large stone on the road? If the difficulty is so great that the carriage cannot advance, it slips on the stone; but I have blocked up the wheels of the carriage with square pieces of wood four inches in diameter, and started it when so blocked up.

In proportion to the size of such obstruction there is liability in the crank to break? Certainly; but the cause which occasions a crank to break is one which cannot be explained on common principles: it frequently happens, as in steam-boats, and very often in this carriage, when the power applied to it is not equal to its being broken, the accident occurs, and must be referred to a jar or percussion; the axles are unusually large in consequence.

What is the throw of the crank? Half the diameter of the stroke of the engine; eight inches and a half to nine inches.

With a wheel of five feet diameter what is the throw of your crank? About nine inches.

What is the length of the stroke of your cylinder? I think 16 to 18 inches; the crank is half that. I may state here, that I have had accidents of breaking the crank two or three times during my experiments: the last crank was broken in consequence of going through some rough stones laid unusually thick; I understand as much as 18 inches deep.

What do you anticipate will be the most frequent accident which will happen to your drawing machines? I should say the derangement of the pumps is most likely to occur, in consequence of which the carriage would merely stop.

During the experiments you have been making, have you frequently had your tubes burst? Very often.

Do you conceive you have remedied the probability of such occurrence? Yes; the first tubes we used were iron gas tubes, which were not welded, but simply "butted" together. The consequence was, that whenever any great pressure came upon them the seam opened; but from practice and experience we found it necessary to wrap over, or over-lap the edges, and weld them from end to end; and now we are not subject to those accidents.

What is the diameter of the tubes of your boiler? We make th m from half an inch to two inches; the best size, I think, is an inch diameter.

To what pressure per square inch do you prove them? To about 800 lbs.; I think they would bear 2,000 lbs.

What is the greatest pressure they would bear? It is impossible to say. I have never been able to burst one when well made, when lapped and welded.

What is the average pressure on the boiler per square inch, in your ordinary rate of travelling? About 70 lbs.

And you have tried the tubes to 800? Yes; we sometimes may work up to 100 lbs. and 120 lbs.; but that is a case of great emergency.

What is the greatest probable pressure it will be exposed to? Never more than 130 lbs.; the safety valve blows at 70 lbs. to the inch; it is generally on the lift on a level hard road. I do not think that the pressure is more than 20 lbs. to an inch on the piston.

Is it likely that persons would ordinarily work with the safety valve on the lift? Yes; or nearly so, sometimes.

Is there not a waste of fuel when you work on the lift? It will be in proportion to the escape of steam from the safety-valve; the pressure on the boiler is 70 lbs.; on the engine frequently it does not exceed 20 lbs. to an inch; and when I was asked the pressure I worked at, I supposed the question referred to the pressure on the piston collectively.

What is the thickness of your tubes? The thickness of the iron is about the eighth of an inch.

What is the thickness of your working cylinder? It is about three quarters of an inch; it has also ribs round it.

Of what metal is your working cylinder formed? Cast-iron; we have worked gun metal, but cast-iron appears to be best.

Have you found that there is great facility in guiding those carriages? I have always found the most perfect command in guiding them.

Supposing you were going at your ordinary rate of eight miles an hour, could you stop immediately, or would the carriage run for any distance? In case of emergency, we might instantly throw the steam on the reverse side of the pistons, and stop within a few yards. The stop of the carriage is singular; it would be supposed that the momentum would carry it far forward, but it is not so; the steam brings it up gradually and safely, though rather suddenly.

Supposing you were going at the rate of eight miles an hour, can you say at what number of yards it would be possible to stop? I would say within six or seven yards.

How would you manage on a declivity? On a declivity we are well stored with apparatus; we have three different modes of dragging the carriage.

You have stated that you found no difficulty in guiding the drawing carriage, or any difficulty in guiding the carriage which is drawn? Not the least; it is peculiarly connected, so that the fore wheels of the carriage drawn follow the tracks of the hind-wheels of the steam carriage drawing, although making a circle of 15 feet diameter, which is a singular property.

In what circle do you think you could turn both carriages? In a circle of 10 feet, the inner diameter.

Supposing you were going at the rate of eight miles an hour, in what inner circle do you suppose you could turn? I should be very sorry to attempt to turn within a small circle. I think I might say, probably it might safely be done in one of 100 feet diameter.

In the further progress of the improvement of this description of carriage, do you suppose that greater weight will be drawn, by adding to the number of carriages; or by increasing the size of the one carriage drawn? The carriage drawn with its load, should never exceed three tons, and the carriage to draw it should never exceed the weight I have previously stated, about two tons or 50 cwt.; it is possible to draw more than one carriage on good roads, but I do not think it would be a circumstance of common occurrence.

What have the chief inconveniences been that you have met with on your journies? The principal inconveniences we have met with have been minor derangements of some parts of the machinery, such as the valves of the pump being deranged, or tanks leaking, or something of that kind. I never met with any serious accident, except perhaps the first accident in going up Highgate Hill, which was five years ago. The carriage was not then complete in referrence to dragging; I went up the hill contrary to the expectations of every body present, and the workmen were so delighted at it that they neglected to lock the wheel; the carriage was started down the hill without any drag to it; it became difficultly manageable, and ran against a stone, and was upset. This is the only accident I have ever experienced myself. I believe Sir Charles Dance once upset the carriage in a first essay.. Those are the only accidents of the kind I am aware of.

It has been stated that one of your engines has blown up at Cheltenham; is that the case? I am not aware of that; I rather believe that the lifting of the safety-valve when the carriage stops is considered to be a bursting, which I think must be so in this statement. I saw the carriages the day after the accident of the crank breaking, where it is stated to have burst, and certainly the carriage had not blown up then; nothing more than the safety-valve had lifted. I came to Cheltenham the day after the accident occurred.

What was the nature of the accident which occurred? The breaking of one of the cranks, occasioned by the extra difficulty the carriage was placed in; new stones were laid in a hollow of the road, I am told about 18 inches deep; the carriage had gone through it twice with twenty passengers; the third time it fractured the axle, from the extra force necessary to get it through; the road was in an unusual state; I saw the passengers of a four-horse coach get down in the stones. I was told at the time, by people of great respectability, that all the two-horse coaches invariably put down their passengers; that the mail was stopped; that there were two wagons and two coaches in the stones stopped at the same time, and that they were obliged to exchange their horses to get through.

Has any other accident occurred to that carriage except that you have now stated? Nothing that I am aware of material.

Have the wheels of your carriages frequently caught fire? Never; I saw the three carriages the day after the accident; neither one had taken fire. I am sorry such an idea should for a moment exist: I think it has been occasioned by misconception or prejudiced mis-statements.

Is the construction of your boiler and of your fire-place such, that it is impossible for the carriage to catch fire? I believe it to be impossible.

You have stated that you require to charge your engine once in seven miles? Yes; to charge the tank with water, and to take fresh fuel.

Do you anticipate, in the course of your experience, that you would be able to overcome that inconvenience of being obliged to charge so frequently? We can now go double the distance; but we should have a weight of water and a weight of fuel, a greater expense to carry than if we take in one charge at seven mile stages.

Are the wheels you ordinarily travel with four inches wide on the tire? From three and a half to four inches.

Have you any information to give to the committee in relation to the relative wear of the tire of wheels and the shoes of horses? That is a new horse shoe [*producing one*,] and this is a shoe of the same size, worn on the streets of London nine days: the shoe has lost about 18 ounces.

Have you any means of ascertaining how many hours a day it had been out? The horse ran in a cab; it was out a certain number of hours, I think, three or four hours each day; the smith was taking off the shoe which had been worn, and putting on the other, when I asked him to let me have them. The difference between the wear and tear of tires and horse shoes on the roads in the neighbourhood of London are in the proportions of about three-fourths on the shoes, and one-fourth on the tires; but in London, over the streets, about seven-eighths and one-eighth. I would observe that on railroads, where horses draw the carriages, the expense of keeping the horse roads is so great, that the proprietors frequently go to a great expense to pave them. From Cheltenham to Gloucester, for instance, and in many other parts of England, this is the case. I would also call the attention of the committee to some parts of London, where the horses and the wheels continue to pass over the same ground respectively, as in Wych-street; and I would submit the importance of the committee referring to the expense of keeping the towing-paths of canals in repair, where only horses, and comparatively few, travel over them. At this moment, those are the only means enabling me to speak to the relative wear and tear.

Have you used your carriages on pavements? Yes; never to run continually on a pavement, but to run in and out of towns.

Do they run easier on pavements than on ordinary roads? Yes; they only take about a quarter the power on a pitched pavement, that is, a quarter of the power they would over a gravelled road.

In the progress of this improvement, do you anticipate that it will be necessary to adapt some portion of the turnpike roads to carriages of this description, or do you think they can be put into operation on the turnpike roads as they are now existing? I think they can be put into operation on the turnpike roads as they are now existing; I have no doubt at all about it.

You do not anticipate the necessity of paved roads being made for the purposes of those carriages? As far as economy goes, in the expense of power, it may be desirable; but for the practical application of the steam it is not necessary.

Can any proportion be drawn between the friction occasioned by the horses feet and the tire of the wheel? I do not see how it is possible to do so, unless you take the loss or abrasion of the two metals respectively, in a given quantity of work or miles travelled over.

Have you any practical experience in the repair of turnpike roads? I have had my attention turned to it, connected only with this subject. I have seen the great expense of keeping towing-paths and horse-paths in repair; and I have seen the great expense of keeping the streets in repair, where horses alone travel; and I have seen the great wear and tear of iron shoes, when compared with the wheels of carriages.

Have you any plan to submit for fixing the tolls on steam carriages? The plan I should propose would be, if I may be allowed the term, that an iron horse of the same weight as one of flesh and bones should pay the same toll; and taking one horse to weigh 10 cwt., that for every 10 cwt. the steam carriage weighs, it it should pay the same toll as one horse pays; although I do not admit that the same weight carried on four wheels will do as much mischief as on four hoofs. If we take the turnpike acts, and look at the comparative rate of tolls charged when a horse is drawing, and when he is not drawing, I shall be, I conceive, borne out in my position.

Can you point to any clause in private bills which press more than you conceive they should on steam carriages? There is one, the Liverpool and Prescot road bill, this session, charging a toll per horse-power, which it is difficult to determine. My objection to that is, that if the horse-power is taken as the nominal engine horse-power, a steam coach would have to pay *2l.* *8s.* where a stage coach pays only *4s.* a toll. The next is the Bathgate, near Edinburgh road, where the tolls are on weight, and an engine of three tons (about the usual weight of a loaded four-horse stage-coach), would have to pay 1*l.* 7*s.* 1*d.*, when four horses would have to pay *5s.* The next is the Ashburn and Totness road bill, where *2l.* would be charged on the steam carriage and the carriage attached, being *5s.* on each wheel; four horses, at the same time, would have to pay *3s.* The next is the Teignmouth and Dawlish roads: they are in the proportion of *2s.* and *12s.*

What is the most favorable instance to steam carriages? The Metropolis roads, near London, charge 1*s.* for four horses, and *2s.* for the steam carriage and the one drawn. I complain of that because it limits me to a particular kind of carriage. I am building one which will not weigh more than 5 cwt. and carry only two or three persons, and it would be excessive to have to pay *2s.* There is no reduction if it is no bigger than a wheelbarrow; being propelled by machinery, it will be charged double.

How many private bills have been introduced this session in which steam carriages have been specially taxed? I have fifty-four, which I now produce. I understand there are others.

Have any of them passed into a law? Yes, some of them have.

In your opinion, what proportion of the tolls should horses and carriages be chargeable with? Taking the average of the amount of tolls throughout the country, it will be found that where a horse pays a penny not drawing, he pays about three-pence when he is drawing. In that case, the toll upon the coach is nominally put upon the horse (it says, so many horses drawing): four horses drawing will be a shilling; four horses passing through, not drawing, will be four-pence; in some cases it is three half-pence a horse when not drawing, and sixpence when drawing; but in general the proportions appear to be, three-eighths the toll placed upon the horse, and five-eighths upon the

carriage; three half-pence a horse not drawing, and sixpence drawing, gives three-fourths; but the mean is about three-eighths and five-eighths; so that the toll is virtually about five-eighths on the carriage, and three-eighths on the horse. I have previously stated that I have had horses weighed, and found the average about 10 cwt. each horse; therefore, if a steam engine weighs 10 cwt. it should pay only as one horse when it passes through not drawing, and as one horse drawing when it has any thing attached to it. A 10 cwt. steam engine cannot propel more than one horse can draw; therefore the weight drawn cannot exceed a certain quantity. If the weight of the engine exceeds 10 cwt. and not twenty, it should pay as two horses; if it exceeds 20 and not 30, it should pay as three horses; if 30 cwt. and not exceeding 40, it should pay as four horses, and so on.

Practically horses drawing frequently draw a weight of 30 cwt.? Yes, sometimes, but 15 cwt. a horse is the usual weight. I have always felt a great anxiety that the weight of the steam engine should not injure the road, and I have felt desirous of not introducing it until it was reduced; and I now cheerfully admit, that if the weight of the locomotive exceeded 60 cwt., which is the weight of the present loaded stage coaches, with the passengers and their luggage, there should be a very heavy toll put on them. I would also propose that if my wheels are wider than four inches, the tolls should be less; if they are six inches, then they should be still less; but taking the principle of 10 cwt. of iron and copper to do the work of one horse, and that it should pay the same tolls, and that no weight of steam carriage should be admitted above 60 cwt. on the road, I certainly should myself be content, and as I cannot for a moment imagine that the 10 cwt. running on four wheels can do so much harm as 10 cwt. carried on four feet, that the interests of turnpike trusts would be fairly preserved by such a scale of tolls.

What is the amount of toll charged between Gloucester and Cheltenham? Five shillings and sixpence.

What would be charged on a four-horse coach? Two shillings and eightpence.

Your steam carriage, according to the last improvement, weighs 35 cwt. without the weight of persons to direct it? Yes, and without the weight of the fuel.

Do you not consider that the steam carriages would be applicable not only to the moving carriages at a rapid rate, but also to moving certain weights at a slower pace? I think it is possible, but it would be very expensive, because I find that when you get below a rate of four miles an hour, the expense in fuel is greater than the expense in horses; if the rate exceeds four miles an hour, then it is cheaper, and it becomes cheaper geometrically over horses as you get up.

What is the greatest weight which you conceive your steam carriages could draw after them on a level road at the rate of four miles an hour, the carriage weighing two tons? Every 10 cwt. in the engine would draw what one horse could draw, so that two tons would draw as much as four horses.

Will the rate of tolls you have remarked in the bills you have produced, prohibit the use of steam coaches on these roads? Certainly.

What do you calculate to be the comparative expense of running a steam carriage and running a coach with four horses? That varies in different situations, according to the price of coke and the price of labor. It is in all cases considerably less, at least one-half less.

You anticipate that the principal use of steam carriages will be the conveyance of passengers, and at one half of the expense at which they travel now? Yes; and in less time.

Can you deliver in to the committee a detailed estimate of the expense of running a steam coach, and one of running an ordinary coach? Yes, I will prepare them.

At what rate do you suppose it would be safe to run steam carriages on the public roads? I have run them safely eighteen and twenty miles an hour; but twelve miles an hour is perfectly safe and practicable. The rate will be determined by practice principally: in directing the carriage at present there is no difficulty or danger in guiding the carriage at this rate.

Would there not be danger in passing a carriage drawn by horses? If the engineer was careless it might be, but not with care; a mail-coach travels far beyond that at times.

You make your wheels cylindrical? They must be cylindrical, for they turn with the axles.

None of yours are less than three inches now? No; three inches to three and a half, even where the carriage weighs two tons weight.

Veneris, 5° die Augusti, 1831.

Mr. *Goldsworthy Gurney*, again called in, and examined.

Will you give in the statement that you were directed to produce on the last examination? I will.

[The witness delivered in the same.]

Calculation as the relative expense betwixt Horse and Steam Power for Locomotion.

In order to estimate the comparative expense between *horse* and *steam power* for drawing carriages on common roads, I will take the relative expense on 100 miles of ground for working a common stage coach *by steam* and *by horses*.

The first cost, wear and tear of the coach *drawn*, in every respect, is the same in both cases.

The expense of men to manage is about the same also. In one case there is a coachman and guard; in the other, an engineer and director.

Government duty and *turnpike tolls* must also be considered the same.

It remains then to show the difference in the expense of POWER only, viz. betwixt the expense of horses and the expense of steam. First in the outlay, on 100 miles of gound. To work a coach well with horses 100 miles up and 100 miles down once a day, will require 100 horses. A horse a mile is the present calculation for doing the work. If these horses be taken at £20 or £30 per horse, or say £25, it will amount to £2,500. *Three* steam carriages will do the same work, and the expense of these will be about £500 each, or £1,500 for the three. A saving will consequently be effected in the first outlay of £1,000 in capital.

The wear and tear of horses may be estimated at about £5 each per annum on the 100 horses, viz. £500 per annum.

The wear and tear of three steam towing carriages will not exceed £ 100 each per annum; £ 300 for the three;—saving in wear and tear, £ 200.

The expense of shoeing, keep, provision, attendance, harness, &c. is per day somewhere about 3*s.* each or £ 15 upon the 100 horses.

The expense of fuel for two carriages, one up and the other down, doing the same work, will be that of 100 bushels of coke at 6*d.* per bushel; say £ 2. 10.

Or if we take 1*s. per mile* per horse power, it will be about the same. The expense of fuel for the steam carriage will be, on an average throughout England, about 3*d.* In some coal districts it will not exceed 1*d.* per mile; while in other situation it will amount to 6*d.*

I have not taken into this estimate the expense of stables which is considerable when compared with sheds for coke and water.

From these data, I conclude the carriage may be worked by *steam* at one-fifth the expense of horses.

Abstract.

Horse power.	£. s. d.	*Steam power.*	£. s. d.
Outlay for horses - -	2,500 0 0	Outlay for steam carriages -	1,500 0 0
		Balance of saving in the outlay in favor of steam power -	1,000 0 0
Wear and tear of horses, per annum - - -	500 0 0	Wear and tear of steam towing carriages, - -	300 0 0
		Balance, saving in tear and wear in favor of steam power - - - -	200 0 0
Shoeing, keep, attendance, provision, harness, &c., per day, for 100 horses - -	15 0 0	Fuel for steam carriages, half bushel per mile travelled, at 6*d.* per bushel - -	2 10 0
		Balance, saving - -	12 10 0

Have you any additional evidence to give to the committee, on points which you have considered after your last examination? I have no further evidence in connection with the practicability of the carriage.

Would you wish to explain your former evidence, or to give any additional evidence upon the subject? On looking over the evidence, I find it correct. I should observe, in explanation, that at 3*s.* a day I have taken in the wear and tear of the horses, and the attendance, and the fuel.

How long are your boilers calculated to last? About three years fair treatment.

How frequently do they require examination? Once a fortnight or three weeks: it depends on the situations where they work. In some situations where lime is held in solution in the water in large quantities, they require cleaning oftener, but in other situations, where there is very little earthy matter held in solution, they will run for a month or two months.

Is there a facility of cleaning them? There is, from recent improvements in cleaning, very great facility.

Is there any expense attendant on the operation of cleaning? One day's work of a laborer, their not requiring an engineer.

You have stated in your former evidence that it would be unjust to put a toll on steam carriages according to the nominal horse power of the engines; will you state why it would be unjust to put a toll in that way? Because I conceive at present there is no standard by which we can fix a horse power.

Will you state to the committee the variations of rate at which the different engineers have calculated horse power? The most generally received standard is 180 pounds at two miles an hour—say from 150 to 200.

Could there be any fair system of toll established by the length of stroke and the area of the piston? I think not; the length of stroke and the area of piston will give power in proportion to the pressure of the steam upon it; the apparatus for supplying or generating the necessary steam would vary considerably in weight in different engines; and therefore the weight of different engines would vary so much perhaps as three times or four times.

Would there be any objection to placing toll on an engine according to its greatest power of working? I think it would be very difficult to ascertain its greatest power of working; it might be done, but it would be very inconvenient.

Are there no means of ascertaining the average power of working? Horse-power is very arbitrary; the best standard which I can give, is the evaporation of water, and I should say that the evaporation of nine gallons of water in an hour, ought to be equivalent to one horse-power. One engineer will apply the steam with more effect from nine gallons of water, and with more general advantage than another: nine gallons may be taken as an average.

What is the diameter of your cylinder, and what the length of stroke? I believe I have given the length of stroke in my former evidence, but not the diameter of the cylinder. The diameter of the cylinder now used is about eight inches, offering 64 circular inches area on the piston.

Is there not on those engines an average rate of expenditure, not speaking with mathematical certainty; is there not the means of calculating pretty well the expenditure necessary to work them? The expense of fuel for working them is well ascertained.

Having ascertained that it will evaporate nine gallons of water in an hour, you come pretty nearly to the expenditure of one horse power? It does not follow in all cases that one horse power will be practically produced from nine gallons; and, on the other hand, I may state that I have seen a horse power produced from five and six gallons.

At what pressure? It does not signify much at what pressure.

You say that the evaporation of nine gallons of water is equal to one horse power; does it not make a difference according to the pressure? This is a point unsettled at present by engineers; some advocate high, others low pressure.

You have stated that if you wished to increase the power of your engine you would increase the weight of it, and decrease the size of the wheels? It might be done either way: the union of the two is not necessary as far as regards the intensity of power: the quantity of power must be produced by an increase of weight, or by some increased or rapid formation of steam.

What is the weight of a loaded wagon, with horses? At this moment I am not prepared to give an accurate answer, but I should think six tons.

Does that include the weight of the horses? No.

What should you judge to be the weight of the horse usually attached? From 14 to 16 cwt. each horse.

Would not you, by increasing the size of the cylinder, increase your power? Yes, in direct proportion with the increase of the area.

What objection do you see to increasing the size of your cylinder, and applying it to a large wagon, so as to use steam carriages for the mere carriage of goods? I think the difficulty and objection lies in the management practically; it would be difficult in our present stage of knowledge and experience to manage a large cylinder very rapidly on the road; but I see no other obstacle to great speed; there is no theoretical difficulty. I would wish to state, in connection with my former evidence with respect to fuel for working slowly heavy carriages, that my opinion was founded on some peculiar laws of momentum lately observed. It is well known that one engine, when worked at a given rate, works expansively; that an engine working at a quicker rate, if a piston only travels half a mile an hour, or 50 feet a minute, it will require more fuel for it to do a given work, than if working at 200 feet a minute.

Is not the momentum gained by greater velocity an accumulation of power? I think the advantage gained by certain rapidity of action, arises from the inequalities of the road being overbalanced by the momentum of the carriage. When the carriage travels slowly, every inequality, every stone or slight obstacle partly destroys the momentum, but at a certain speed it overcomes them. There is no actual gain of power by momentum; it is only an accumulation very much like that in a common fly-wheel, and in a carriage on a common road: it acts on inequalties as a fly-wheel does in overcoming unequal obstacles in machinery.

You use coke only? We occasionally may use charcoal, but very seldom.

What is the proportion in price, and what in value, between coal and coke? I think one bushel of coals is equal in raising steam to two bushels of coke.

What is the difference of price on the average? The difference of price is, I think, about two-thirds.

Then there would be a loss, as compared together, in using coke? Coals would be much cheaper than coke, but that loss in the expense of fuel we are disposed to suffer rather than produce a nuisance on the road by smoke.

Do you conceive that there can be no mode of escaping that by any smoke-consuming apparatus? I know of no mode that is likely to succeed, nor do I conceive that it is possible to make such a combustion of coals that is likely to consume all the sublimated or volatilized matter: the consuming of smoke or the combustion of smoke is prevented principally by the particles being mechanically mixed with, or surrounded by, carbonic acid gas. I believe it not to be chemically combined.

Would not the motion of the carriage and the current of air that is produced by going quickly through the air, give great facility in the application of a smoke-consuming apparatus? If the consumption of smoke depended on the presence of oxygen gas or atmospheric air which contains it, I think it would; but on my previous reasoning, I do not think the consumption of smoke would be effected by any quantity of atmospheric air. I have made several very extensive experiments on this subject, and the only experiment that I have succeeded in, was by passing it through sand mixed with quick lime, by which the carbonic acid was absorbed, and the smoke, as it passed through the mixture, rendered combustible; the carbonic acid was removed to a considerable extent, and left the carbonic oxyde and hydrogen gas in such a free state as to be combustible.

Of what materials are your propelling wheels? The same as a common stage coach wheel.

Are the wheels of the carriage drawn nearly of equal diameter with the wheels of your drawing carriage? Rather less; the diameter of the wheels of the drawing carriage is about five feet, and the ordinary diameter of a stage coach that is drawn is about four feet six.

From the experiments you have made, supposing the drawing carriage and the carriage drawn were of equal weights, what do you think would be the different proportion of weight, on the wheels? None.

Do you speak that with any certainty? Yes, I do. I have taken the loss of iron upon coaches after knowing the number of miles they had travelled over, and the loss of iron on the steam carriage, and the number of miles it had travelled over, and find that the loss in both cases bore the same proportion.

Is coke alone used on the railways in the locomotive engines? On the Manchester and Liverpool railroad, I believe there is a clause in their act to prevent any nuisance being made by smoke, and coke is therefore used; but in the ordinary railroads in Wales and other places coal is used.

In what part of your engine is your safety-valve situated? It is situated at the option of the engineer; frequently in the steam pipe leading from the boiler to the carriage, most generally; so that the steam as it passes through that pipe, may lift the safety-valve, or it may go to the engine, as the state of pressure shall determine.

Do you make use of one or two safety-valves? Only one. I occasionally use two, but we now use only one.

If your carriages were brought into general use, would you suggest that two safety-valves should be required, one out of the reach of the engineer to prevent accidents from occurring from racing, or other causes which could induce the guide to increase the pressure of steam? I should recommend one being locked, and an inspector being appointed to examine it every journey. Perhaps I may be allowed to make an observation or two with respect to the bursting of boilers, which subject, I believe, is now under consideration. From experiments which I have made in connection with this subject, I am led to believe that the bursting of boilers is not always occasioned by pressure of steam. I have discovered that, at a certain degree of temperature, and under certain circumstances, when water is decomposed, that the hydrogen is often formed into a new state of combination with oxygen and nitrogen gas, which compound is exceedingly explosive; so much so, that I believe scarcely any provision that we can make in the shape of a safety-valve, would protect the vessel. This was a subject which I was led to some time ago, from some observations which I had made on the combinations of oxygen and hydrogen only. I had some conversation with Gay Lussac on this subject, and he was of the same opinion with myself, particularly that there were different chemical compounds of hydrogen and oxygen gases which at present were not acknowledged. The only one acknowledged in this country is that forming water. A compound of two proportions in volume of oxygen and two of hydrogen, has been chemically combined in Paris, although I believe we have never succeeded publicly in this country. This compound was highly explosive when brought in contact with certain substances,

It would be by expansion? By chemical contact; if brought into contact with certain substances, it would be affected as to produce explosion. I have

reason to believe from some original experiments, that there is a compound of these elements produced under certain circumstances in steam boilers. The want of water in a boiler is favorable, in which case the temperature is raised and the compound formed; the bursting of boilers I believe frequently takes place, from this compound coming in contact with substances that will decompose it, and perhaps I might mention this fact, as it is a very interesting one, namely, that boilers often burst when the vavles are known to blow at a pressure very considerably lower than the boiler has been proved to.

Does not that take place also when the water is in the boiler? If the water is low in the boiler, it will take place; if it is high, never.

Has it not frequently happened that boilers that were calculated for a higher pressure, have even burst at a lower pressure than they were intended for when water is in them? When water is high in them, never; but when it is so low in them as to form this chemical compound, it does. I would state a fact which was mentioned to me by my friend Sir Anthony Carlisle, which throws considerable light upon the subject, and first led me to my suspicions and experiments respecting it. The case was, that a boiler at Mr. Meux's brewery, with an open top—a common cauldron—burst with a violent explosion. I believe one man was killed, and two very severely scalded. There was no cover at all on the vessel. This phenomenon, upon inquiry, appeared to be occasioned by gelatinous matter, forming a crust, a film, or blister, and prevented the contact of water with the bottom of the boiler. The bottom of the boiler consequently got hot; the compound I alluded to was formed, or the rupture of this film, and the sudden contact of water against the hot surface below, produced such an immense and sudden volume of steam, that it burst the boiler. I would explain it by saying it was analogous to the bursting of a gun, in which case an ounce or two of shot is placed only against the charge. Whenever there is a sudden formation of elastic matter and there be ever so small a weight opposed, the shock will be very great, and a gun will frequently burst, though there is not an ounce of shot in it, and which charge may be considered in the light of a safety-valve in this case.

What precautions have you taken in your boilers, that there may be no probability of their being without water? This compound never forms without a certain raised temperature. Before this temperature, necessary for decomposition, takes place, it melts a fuseable compound alloy of metal, placed so as to allow of its escape. The matter formed escapes, and all danger is prevented.

Have you any precaution to prevent the water escaping out of your narrow tubes, by bubbles of steam? Yes; that I would explain by reference to the first drawing, (No. 1.) which will show that the bubble of water, as it escapes from a tube in connection with a part of the boiler, is supplied simultaneously from the lower part of the tube, and a stream of water is thus made constantly to pass through.

Would not that stream of water act as a safety-valve? When there is water, it is sufficient, but when water gets down in any boiler, there is no safety-valve that will protect it, and hence arise the inexplicable accidents that have occurred frequently in steamboats; the size of the boiler is the only protection without the safety alloy.

Have you any guage, or means of ascertaining when there is a defiency of water in the boiler? Yes; the melting of the safety plug, I would state, on

ly takes place in cases of great negligence, or in cases of extremity. The guage by which we ascertain the quantity of water in the boiler, is the common glass guage, well known to those acquainted with the subject.

Have you any guage to examine the intensity of the steam? Yes, we have a piston which is forced out in proportion to the pressure; in addition to the glass guages, there are also stop cocks, so as to ascertain, by turning them, the actual height of water. I beg to state, that the safety plug has never, but four or five times, given way in all my experiments, and that has been in cases where we have been accidently out of water in our tanks; no personal mischief can arise from such an accident. I am satisfied, without this plug, an explosion would have taken place in some of the tubes. In large boilers, under these circumstances, inevitable destruction would have attended it.

Are you aware of the size of the cylinders and stroke of the engines on the Manchester and Liverpool railroad? I believe them to be ten inches diameter, and about fourteen inches stroke. In some of the later engines, I believe they have been made of fourteen inches diameter, the stroke being the same; but I rather think that that size has been given up, and that they have returned again to the ten inches diameter.

What is the greatest weight, in proportion to its own weight, which any carriage draws on a railroad? A carriage was originally supposed to draw only three times its own weight on a railroad; but in some experiments which I made in Wales with Mr. Crawshay, of Cwrfaithfa Castle, we found in an experiment, that a carriage draws thirty times its own weight. He has the minutes which we made upon the occasion; but I believe, in practice, they scarcely exceed five times, or from five to ten.

You have stated that in your carriages you do not anticipate drawing more than the weight of the engine? Practically, on the common road, weight for weight. I explained, in my former evidence, that it was possible to do more under favorable circumstances; but circumstances vary so much on the common road, that we ought not to calculate on doing more than weight for weight.

The diameter of your steam-wheel is rather greater than the diameter of a carriage-wheel? Yes, the size of the wheel I proportion to the engine, so that the piston may work under the most favorable circumstances.

It is by experiment simply that you have arrived at your present size of cylinder? Yes.

You stated in your former evidence, that you anticipated that passengers would be carried at one-half the rate by your steam carriages that they are by the common carriages; what difference in the ordinary expenses of carriage would it make if you had a paved road for this purpose? I think that it would reduce the expense to one-half again.

If there were properly paved roads, you conceive that passengers might be carried at one-fourth the present expense? Not exactly; because the total expense includes the government duty, tolls, &c. as the same; but as far as the steam-power is concerned they would. These subjects have been inquired into by a mathematical friend of mine, and he has published the result of his inquiries, which I will take the liberty of delivering in.

[*The witness delivered in the same.*]

You have stated that, in certain states of the road, you find increased difficulty than in other states? I have; and the difficulty arises from a mechani-

cal application of the steam simply; namely, in consequence of the road being in a greasy state, and the wheels therefore more easily slipping, and, under the circumstances, do not furnish so good a fulcrum for propelling.

Have you ever watched the operation of your carriages in snow? I have; I have used them both on snow and on ice. On ice, a very little roughing of the wheels is necessary, in the same manner as you rough horses, and little power is sufficient to propel the carriage, because, under those circumstances, the power to draw the weight is very considerably reduced, and therefore the full power of the engine is not necessary to be exerted; in deep snow, there certainly is great difficulty; but I have no doubt that as the subject goes on improving, all those practical difficulties will be overcome.

The difficulty would be greater in your carriage than in other carriages, would it not? I think not; I think the carriage might be so constructed as to remove the difficulty.

Will you state effect of ice below, and snow above, upon the action of your carriages? I have had occasion, in two or three instances, to use the carriage under those circumstances, with a view judging of the practical result of it; and I have not found any difficulty in its progress. The snow is pressed strongly under the wheel, becomes almost immovable, and furnishes a good fulcrum for the wheel; a little preparation is only necessary, and a very little is sufficient to overcome any moderate obtsacle of that kind. May I be allowed to give in to the committee a scale of what I conceive to be an equitable toll on steam carriages? it is the same in principle as I gave in on my last examination, but is extended.

[*The witness delivered in the same.*]

To what width could you extend the tire, without any inconvenience to the working of your carriage? At present I cannot say to what limit it may be carried, but six inches would be no inconvenience.

Then your carriage would go with six inches tire? I think so; and, under certain circumstances, easier, where the crust of the road is hard.

Would not that depend very much upon the road? It would; I would state general principles: I would submit to the consideration of the committee, better to explain my meaning, that it frequently happens that a frost forms a crust sufficiently hard to support the weight of a carriage a ton weight, but that it breaks under one or two tons; the power required to draw two carriages respectively so circumstanced is so great, that I can give you no data for estimates off-hand; but it is evident, that the power of drawing a one-ton carriage would be little compared with the proportion of power required for drawing two. My answer to the question is, generally, as I find the public roads at this time.

To what velocity could you increase your present rate of travelling with your engine? I have stated that the velocity is limited by practical experience only; theoretically it is limited only by quantity of steam; 12 miles, I think, we might keep up steadily, and run with great safety. The extreme rate that we have run is between 20 and 30 miles an hour. I stated in my former evidence, that the carriage when upset by Sir Charles Dance, was, at that time, going at 18 miles an hour, but no injury happened either to the machinery or the persons upon it: still I am of opinion that that speed might be maintained with perfect safety by a little experience in practical management.

What are the practical objections to going at that rate? I think the principal objections are want of real knowledge and experience: I have been so many times disappointed in what theoretically I had imagined true, that I am afraid to give a decided opinion on subjects not practically proved.

Have you any thing further that you wish to state to the committee? I would state generally, in regard to the main improvements on steam engines, by which this country has been so much benefitted, and the prospects of advantages arising from steam carriages, that they have almost always been in a direct ratio with that of removing of horses; that the great and splendid improvements of Mr. Watt have generally been supposed to be principally connected with the separate condenser of the steam engine, and the saving of the fuel; but before Mr. Watt's day, we could empty our mines of water in Cornwall, and we could do a variety of other simple work by the steam engine, and so far the improvement of Mr. Watt was simply with respect to the saving of fuel; but I consider that the great national advantage arising from Mr. Watt's improvement, has been his application of the steam engine to machinery; and the extent of that advantage to the community has been in a direct proportion to the removal of horse power, a most unproductive laborer, and a dead expense to the country. If this view of the subject be entertained, the application of steam to propelling carriages on common roads, will be as important above its application to machinery generally, as the number of horses employed in locomotion exceed those necessary to machinery, which bears no proportion with respect to each other. At Hounslow alone, there are, at this moment, upwards of 1,000 horses employed in stage coaches and posting. On the Paddington road, a distance of five miles only, there are upwards of 1,000 horses employed at this moment. Throughout Great Britain, it is almost impossible to say how many horses are employed, but I should perhaps be within bounds if I were to say millions, in posting and stage coaches. If it is possible to remove those horses by an elementary power, which I firmly believe is practicable, the national advantage must be in proportion to the nnmber of horses so removed; for if it is shown that one carriage horse can be removed from the road by the present state of steam carriages, I see no reason why every horse so employed should not be so removed. It has been decided that the consumption of a horse is equal to that necessary for eight individuals, so for every horse that is removed and is supplied by elementary power, we make way for the maintenance of eight individuals. If it is possible to carry the idea so far, and I see no objection to it, to do the principal work of horses by steam, or if it can be done by elementary power, the committee may imagine to what extent we may provide for our increasing population. I think we may do much by political laws and enactments, but natural laws will do more, and when pointed out by the finger of Providence, may be made to provide for his wise dispensations. I firmly believe that the introduction of steam carriages will do more than any other thing for this country. I have always had this impression; I left an honorable and lucrative profession, in which I was extensively engaged, in order to attend to this subject, because I was convinced of its importance and practicability; I have always entertained the same idea as I do at present. Imperfections will exist in the machinery; but I conceive that the main points of difficulty have been removed by the experiments I have made, and that all those now remaining are practical difficulties, which will be removed by further experience; and if there is no cause opposed by the Legislature, or any other source, I will be bold to say, that, in five years, steam carriages will be

generally employed throughout England. I have not hesitated, having these feelings, to devote all my time for the last six years to the subject, and am mentally recompensed by the present state of the subject. Private carriages also will be used. Under this opinion, I have given directions for building a small one. I expect it will go quicker, safer, more easily, and certainly more independently than a common carriage, because it does not need the food of a horse.

Do you apprehend much decrease in the price of your engines? I do, and I also anticipate that steam will be supplanted by the use of other elementary power; but I do not think that will take place in our day. I think that steam will be generally introdueed, and that the publc will feel the import tance of it; and that scientific men will be directed to examine and employ in its stead other substances, and new compounds are continually turning up, and some will eventually be applied to mechanical purposes.

Do you believe that there will be other ways of raising steam? I do not now speak of steam, but certain compounds. I do not specify any particular compound at this moment. I state those generally which are known to produce power by chemical change: some peculiarly explosive and aeriform bodies for instance. I am informed that at present there are between 20 and 40 different carriages building, or about to be built, by different persons, all of which have been occasioned principally by the decided journey which I took of 200 miles in 1829, and which convinced not only the public of its practicability, but also some of those very men who are now employed in this object, and who previously had laughed at the idea, and considered it chimerical.

In what particular point of machinery does your patent consist? I have three patents, the first for the boiler, the second for the peculiar application of it, and the third for improvements that have been made since.

Do you anticipate much saving of fuel in your future experiments? I do; I think the saving of fuel will be in proportion to the saving of water.

That is, that there will be a saving from the better application of the fuel and boiler? Yes; and from the general improvements in machinery. For instance, it is an unsettled point at this moment whether a pressure of 20 lbs. to an inch, or 120 lbs. to an inch, is best. It is not yet decided, which time will decide.

Do you cut off your steam, so as to work expansively? Yes, we generally work expansively.

You have mentioned that various accidents had happened to the crank of the engine, which were not accounted for: have you in contemplation to effect any change in the application of the power? At present, I think the crank the most simple; in some of my first experiments I worked with a chain passing over two wheels from one to another; also by a rack and pinion, and various motions of that kind; but I think that nothing is equal to a crank: that also is the opinion of others besides myself. Upon the Liverpool railroad they first applied the power to the outside of the wheel, but they have come to my drawing (No. 3.) at last, and they now work by the crank on the axle: this practically confirms my opinion. There is one observation which I would at this moment make in connection with my former evidence. I have been frequently asked, what would happen in case of an accident happening to the guide or director, in case he falls asleep, or in case he is disengaged from his seat? I have provided for all those casualties, distant as they are, by making the valves of the engine only remain in gear

when the guide is in his proper situation: the moment he is thrown off his seat, by accident or otherwise, the engine instantly stops.

Does that depend upon the guide's weight? No; it is by his foot he keeps the valves down, and the effect on the carriage when he takes it off is very singular. I merely mention that fact in connection with the practical detail and safety of the carriage. The same contrivance, by simply lifting the foot, prevents the carriage from running down hill too quickly, and we do not require the complicated drags that were before used.

Mr. Walter Hancock, called in, and examined.

Are you the proprietor of a steam carriage running on a turnpike road? Yes.

How long have you been running that steam carriage? I dare say about a twelve month this present coach, but I have been working for hire on the road only a month.

Are you the inventor of that particular description of engine that you make use of? Yes.

Will you state the progress which you have made in the improvement of your steam carriage? The principal improvement I consider is in the boiler; that of constructing the boiler much lighter than any that are now in use.

Will you be kind enough to give a general outline of your plan? There are flat chambers which are placed side by side, the chambers being about two inches thick, and there is a space between each two inches; there are ten chambers, and there are ten flues, and under the flues there is six square feet of fire, which is the dimension of the boiler top and bottom. The chambers are filled from half full to two-thirds with water, and the other third is left for steam: there is a communication quite through the series of chambers top and bottom; this communication is formed by means of two large bolts, which screw all the chambers together; the bottom bolts the bottom part of the chambers, and the top bolts the top part of the chambers; and by releasing those bolts at any time at all the chambers fall apart, and by screwing them they are all made tight again. We have braces to fasten them; the steam is driven out from the centre of one of the flues, and the water is ejected from the pump at the bottom communication for the supply of water.

Does the fire pass between the boxes, or does it pass through them? It passes only between them.

There is no line of communication for the fire made between the boxes? Nothing more than the flue through which the fire passes; the sides of the boilers form the chimneys.

Have you ascertained what pressure such boilers are equal to? I have never gone beyond 400 lbs. on an inch. I have worked it on a road at 400; the average pressure on an inch is from 60 to 100.

At what pressure do you set your safety-valve? Taking the average of roads, I work at about 70 lbs. upon the square inch.

You have calculated how may square feet of boiler? At the present carriage, I have 100 square feet of boiler exposed to the fire.

What distance do you run from stage to stage? What I consider the stages I have run is four miles; but every eight miles I take in water; I go there and back.

You consider your stage eight miles? Yes.

Do you take in both water and fuel at the end of a stage? Yes, at the end of every eight miles.

What quantity of water and what quantity of fuel do you use for each stage? About 7 cwt. of water, and sometimes eight; it depends upon the roads; we consume more steam when the roads run heavy.

How much coal or coke do you use for each stage? About two bushels of coke.

Do you mean that you take two bushels at the commencement of each stage? I take more with me, but I always consume a quarter of a bushel per mile.

You do not in that include your first charge of coke when you set off? No, that would vary according to circumstances. If I were in a hurry, I could get the steam up in five minutes; but the average time is about twenty minutes in getting up our steam, and we do not consume more than a bushel.

That is at first starting? That is at first starting.

Do you apply a second carriage to your engine for passengers, or do you carry them in the same carriage? The boiler is placed behind the carriage; there is an engine-house between the boiler and the carriage; the engines are placed perpendicular between the passengers and the boiler, and the fore part of the vehicle is for the passengers, so that all the machinery is quite behind the carriage, and the fore part of the carriage entirely for the convenience of passengers.

Where does the guide sit? In the front, the same exactly as a coachman in a common stage.

How many passengers have you carried? We carry ten; but I am making provision to carry fourteen.

What is the weight of your vehicle? I should imagine about three tons and a half.

Have you ever weighed it? Not this carriage, but the carriage I had before, the vehicle itself with the engines and boilers, weighed three tons. I consider the present carriage to weigh from three tons to three and half tons, with fuel and water.

Have you found the rate of tolls that have been charged at the turnpike gates very high? On the city road toll, I have paid a shilling. I do not know whether it is according to proportion, for it was a thing that did not embrace my attention at that time; but the highest toll that I have paid is a shilling; but on the road that I run from Stratford to London they told me they would not take it; they would take it another day.

What effect do you think your carriage has upon the road, in proportion with a carriage equally loaded with four horses? I think, myself, we should rather improve the roads by the operation of our engines, because a steam coach requires broad wheels, perfectly upright and flat on the outside of the tire.

What is the breadth of the tire? The tires of the present wheels are about three inches and a half.

What is the diameter of the hind wheels? Four feet. That is not a proportion that I consider to be working as a profitable diameter; I consider that the diameter that should be used for a steam coach is at least five feet.

How wide could you make that tire without losing power? It depends on the weight; but taking the common coaches, I should say from six to eight inches.

Without injuring the power? I have no doubt it would be no drawback on the power.

Do you consider that such breadth would be as good as any other, the best you could make? Yes; because a broad wheel on gravel is considered to be a great advantage; it is a great disadvantage on a road which is between wet and dry; but in those cases we have always an overplus of power blowing off at the safety-valve, and, from that circumstance, I am rather pleased at having rather a dead road to run upon, because we are obliged to construct the vehicle so as to overcome all obstacles in the road, such as dead gravel, &c.

To how many of your wheels do you apply your power? To two; occasionally one.

Do you apply it to a crank? The axletree of the present carriage is made precisely the same as the common axles now in use, straight and merely bent at the end, and I have a chain which I put on the nave of the wheel, and that communicates with a corresponding chain wheel on the crank shaft of the engines.

What is the size of the circle on the wheel to which you apply your chain? About ten inches.

How wide is the corresponding circle on the crank shaft? The corresponding pully of the shaft is just the same; so that the power of the engine is the same exactly as though it were applied to the wheel itself.

You have two wheels; how do you move the first wheel? There are two engines working on two cranks, exactly on the same principle as used in common for steam coaches. I take the chains; I place the engine four feet from the axletree of the hind wheels, and the communication of the chain is to allow me to put my work on the springs; and the play of the carriage up and down is accommodated by the chain.

Is your cylinder on springs? Yes, every thing on springs.

Do you make use of one or two cylinders? Two.

What size? Twelve inches in the stroke, and nine inches in the bore.

Has your engine met with accidents? No, except once I broke my chain; but in the course of five minutes we could replace that chain, by taking an extra chain with us.

Are your boilers easily cleaned? In all the experience I have had with the working of boilers, I have found that they never require cleaning. I consider that the ebullition is so rapid, and the action of water so violent, tha it will not allow any dirt to fix.

How long do you calculate one of your boilers would last? It depends upon the thickness of metal. The boiler we use I consider will last, in locomotive engines, from a twelvemonth to two years.

What is the thickness of the iron that you use? I should suppose about the eighth of an inch thick.

Of what material are they composed? Of the best charcoal iron.

What is the appearance of your carriage; has it an unsightly appearance? I think my present carriage is any way from being handsome, because it has been built entirely for experiments.

Does the chimney rise above the carriage? No, you cannot see the chimney.

When steam is let off, where is it let off? You can see nothing of it.

Then there can arise no annoyance either from smoke or from waste steam? None at all.

Do you find that horses are frightened by your carriage? I think I may say safely, that not one horse in a thousand will take the least notice of it;

occasionally a horse may shy at it. I have seen fine blood-horses come along and shy at a wheelbarrow lying in the road, and not shy at my engine. There is one very curious instance which I had once occurred, and I was obliged to the gentleman for the pains he had taken. He had a fine horse on the road and this horse shyed: he was determined to get over the difficulty, if it were possible; and to make him acquainted with it, he came with the engine to town; and at last, when we got to London, the horse got quite tranquil, so that he put his head in the engine-house, which is very uncommon, and which is a thing I never saw a horse do before.

Then you anticipate that if such engines become more common, there will be less difficulty in this respect? I have no doubt of it.

Does it produce any very extraordinary noise in its motion? We have worked so quietly latterly, that I have almost run over people on the road, and they have not heard me. I have had to halt very often: they have not been aware of the coach coming.

Under any circumstances, the noise that is anticipated would take place from the defect of the machinery, and not from the machinery itself? Yes; we make one-third of the noise of a common stage.

When you let off steam, does it produce any violent noise in stopping? I can give an instance to the contrary which occurred in London, which is the best place to put the thing to a test. About a fortnight or three weeks ago, Mr. Wilks was kind enough to mention my running on the Stratford road, and I wished him to present a petition from me to the House of Commons, and at the same time requested that he would take a ride with me in my engine on the Stratford road. I waited three quarters of an hour for him, and the machinery was working the whole of the time; there were hundreds of people walking round it, and I suppose they did not know it was working at all; there was no noise at all in the machinery; and you could not, unless you had gone to the back, known that it was working.

Does spare steam pass off without noise? Not any.

Supposing that you were going at full work, and that you had occasion to stop for a passenger, you would be obliged to let off steam? Yes; but knowing from experience how to obviate a disadvantage of this kind, which of course practice alone has brought to bear, it is probable that a stranger would hardly know it, it is so quiet.

In what part would it be thrown off? It is divided and thrown off from the fire in every direction, and it is instantly consumed; the force is spent.

Is not that rather a dangerous experiment to throw a great body of steam upon a confined fire? No, we have never found any disadvantage from it.

In no circumstances in which the engine may be at work, have you to let off steam in a way to create a noise? No, the boiler will not hold any quantity of steam; we let off steam from the safety-valve as fast as we make it; there is no capacity for accumulation; the fault of many of the boilers is, that if any accident happens there is a complete explosion.

Then, of course, the danger is lessened? Yes, to construct a boiler of that kind has been my object, so that the steam may be let off.

Suppose if one of your boilers were to burst, what would happen? I will give the committee an instance. I was travelling about nine miles an hour at the time the boiler was the twenty-fourth part of an inch thick. I was working then at 100 lbs. on the square inch, with 13 persons on the present vehicle that I have now in use; and all of a sudden the carriage stopped, and for what reason I was at a loss to know. I got from my stage seat and went

to the engineer to ask him what was the reason he had stopped the steam; he told me he had not stopped the carriage, and he immediately applied his hand to the guage cocks. I found there was neither steam nor water in the boiler. I immediately knew that the boiler was burst; they said they did not know it, as they heard no noise, and I told them that I did not mean they should know it. I said I would show them that it was so, and I took the boiler from the carriage and unscrewed it, and there were four large holes that I could put my hand into. This occurred from the chambers being too thin, and they drove all the water out of the boiler, and yet there was no injury to any person; there was not one person that heard any report; there was no steam, and there were no symptoms in any way that the machine itself had burst.

Do your boilers extend under the place where passengers sit? No, quite at the back.

What is the length of the carriage? About 16 feet, and the room the boilers occupy is about three feet.

Are the chambers of the boiler placed upright side by side? They are placed sideways.

In what circle could you turn your carriage? The circle of the inner wheels would be four feet, and the outer wheel would exceed that by the breadth between the wheels: taking the average it would be ten feet.

Supposing you wanted to turn round, what should you do? If I got into any difficulty, and wished to go back, by applying my hand to the lever I should reverse the motions and run the reverse way.

Supposing that you are travelling in a street of ten feet wide, and that there was another street of ten feet wide branching off at right angles with the first street, would there be any difficulty in turning into it? Not any; but I could not turn round in that street. In that case, I should back the engine.

Would you check your speed? That would depend upon the speed I was going at. If I was going at six miles an hour, it is probable that I should not check the speed; but if I were going ten miles, it is probable that I should before I turned round into the street.

Are your fore-wheels and hind-wheels the same diameter? The fore-wheels are three feet three, and the hind wheels are four feet.

Can you reverse the action of your carriage with great ease? Yes; by simply pulling a lever: it is done momentarily. In my present carriage I could not; but I have an arrangement of that kind in the other carriage which I am making.

Supposing you were going at the rate of eight miles an hour, and that you wished to stop suddenly, in what number of feet could you stop your carriage? I will say twelve feet.

Of course there is equal facility in avoiding any particular object on the road? Yes.

In stopping so suddenly, would there not be a danger of your being thrown off? No, I think not.

Have you ever done it? Yes, I think I have.

Supposing you wanted to stop in the quickest possible way, at what distance could you stop at that rate of speed? About four feet, I should think, by backing the engines, because it is like putting a block to the wheel.

Would there be no danger in that? No, I think not; it would throw a strain on the engines; the rate of eight miles an hour is not so great; it is only in extreme cases that that would be done. I am very frequently obliged to pull up very short, from children running in the road.

Of what materials are your wheels made? Like common dished wheels, they ought to be perfectly cylindrical. I merely took them to avoid expense; they were wheels which I had by me.

Are you proprietor of any other coaches? No.

Have you any means of ascertaining the proportion of friction that there is on your wheels, and those drawn by horses? No; I have never gone into experiments to any extent upon that point.

Are your wheels shod frequently? No, I have never had occasion to have the wheels shod; they were not worn out.

For what number of miles could you run without being obliged to shoe your wheels? I do not know.

Do you find any difference of wear between your propelling wheels and your drawing wheels? No, except in relation to the weight on the hind wheels. We throw more weight in order to produce friction, to get adhesion to the ground.

Have you any scheme of tolls to produce to the committee, which you think would be equitable to lay on steam carriages for the use of the road? I have considered the thing a great deal, and, after taking every thing into consideration, the weight of the engine and the weight of the boiler, and so on, on the one hand, I think it is much upon a par with the weight of the horses, and the weight of the coach, and the weight of the passengers, on the other.

What would you consider the most equitable mode of charging steam carriages? I think there can be no better mode than charging them as other coaches are charged.

Supposing that a common coach at present takes eighteen persons, and you, by improvement of your coaches, could take thirty-six persons, how would you apportion the rate of tolls that you ought to pay? In that case, I think the fairest way would be to have it in proportion to the number of persons that are carried.

Do you think it should be charged by weight? That, perhaps, would be as fair a way as any of charging the toll.

Charging the weight of your engine as compared with the weight of common coaches? Yes.

Have you turned your attention to the improvement of your machine, by affixing a carriage to it, and making your engine independent of the carriage? Yes; I have considered the thing well in every point, and I think it is much better to construct the carriage both for passengers and machinery on one arrangement, not to have the thing divided: my reason for considering it an improvement is this; for instance, if a new road is made, the object of the proprietors of that road is to get as heavy a roller as they can, even if it requires eight horses to draw the roller. They do that in order to imbed the gravel to make it solid; and the nearer that steam coach approaches that roller, the better it is for the propelling wheels.

With respect to the tolls, are you satisfied with the present tolls you pay? I think they are exhorbitant: from Islington to the city road they charge me a shilling.

Are you aware what four-horse coaches, with eighteen passengers, pay on the same road? I am not aware.

From what cause do you judge it excessive? From the short distance which I come. I do not know what length of road I should have had to run before I should have been subject to another toll.

Have you considered the subject whether it would be more equitable to charge the steam carriages by horse-power or by weight, or by the number of passengers? I think the fairest way would be in proportion to the number of persons they carried, or in proportion to the weight.

What would you give as the basis of your calculation, considering that the number of persons which the different coaches carry varies from eight to eighteen? I see no other way, excepting that of the number of passengers, or according to the weight.

Have you made any calculation as to the number of horses that the extension of these carriages will displace with respect to each stage; what horse power is equivalent to the carriage that you run? I take a stage to run 100 miles a day, and I reckon upon the average it would take from from 48 to 50 horses for the whole distance; the common average is a horse a mile; but from the information I have endeavored to get, from what I have gathered, I find it about 48 or 50. I believe it is to be taken backwards and forwards at a horse a mile.

Would your carriage displace along the road four horses on each stage? Two ten-horse engines would displace the whole number of horses along the stage.

Have you made experiments which enable you to answer these questions? I was not at all prepared; my principal object has been to ascertain what power I have to do a certain work. I have paid very little attention to horse power.

Do you think that your carriage is equivalent to a four-horse carriage on the road, in the number of persons it would draw? It is more than equivalent to it, from the circumstance of its being able to do more work.

Supposing you have to run seven miles, how many passengers could you carry at your present speed? Fourteen.

Supposing that a coach of four horses were to run that seven miles, how many passengers would it take? It would carry the same number.

What weight, upon a dead level, will set your carriage in motion on the road if you were to attach a rope to the pole, and suspend that rope over a pulley, and attach a weight to it, what weight will set your carriage in motion? It is an experiment I never tried, and I am not prepared to answer.

Do you know what, if you were to set your carriage on an inclined plane, is the inclination that will set it moving? No, that is not a thing which I have tried.

Do all the wheels follow in the same track? Yes, they do.

Have you ever tried your carriage up hill on an inclination? Yes, I have, repeatedly.

Do you find an increased difficulty in proportion to the length of the inclination? No, we go much slower; but we never find any difficulty.

Have you ever found your wheels slip? No, excepting once on the city road, at the time when the frost was on the road; it was quite slippery; and then, for an experiment, I tried to see if I could run up the Pentonville Hill with one wheel only; and I did, but it was with some difficulty towards the top. If I had propelled by the two wheels, there would have been none.

Have you found at what inclination in a frost the wheels will begin to turn? I never witnessed such a thing.

Are you aware that such a thing will occur? Yes; but I think there are no hills which are to be found, upon which horses travel, but what a coach would propel itself up.

Have you ever seen your carriage get into a deep rut? Yes.

In such a case what generally happens? If it is a single wheel, it may go round two or three times; if I have two wheels, it is improbable I should get into such a situation.

Do you find peculiar states of the roads upon which you travel, more disadvantageous than others to the progress of your carriage? Yes.

Which do you find the most disadvantageous? When the roads are between wet and dry.

In going down a hill, are you obliged to lock your wheel in any way? Yes, if it is much down hill; it depends upon its inclination.

What is the nature of the provision for locking the wheel? A metallic band, bearing upon the outer part of the wheel.

What are the fares that you take, higher or lower than ordinary stages? They are the same fares as the stages fares; eight-pence from Bow, and nine-pence from Stratford.

How much is that a mile? Barely two-pence a mile.

In what proportion to what is charged by stage coaches do you think you should be able to charge your fares? I think the fares would be reduced to two-thirds, after a short time, if supported and not overburdened by tolls.

Should you be able to continue running if the fares were reduced to two-thirds? Yes.

In your present state of knowledge upon this subject, in what proportion do you think the rate of travelling would be diminished? In the proportion I have stated of two-thirds.

Is it your opinion, that, generally speaking, it would be reduced two-thirds? Not in the outset, but after the thing has had full play.

Have you made any calculation of the expense of running a coach drawn by four horses, carrying a certain number of passengers, and that of running with one of your carriages at the same velocity? I have endeavored several times, but I have never been able to get an accurate account of the power and other expenses incurred in driving a long stage; but I reckon my own expenses will cost from three to four pounds a day, including all expenses attached to the coach, wages for engineer, steersman, fuel, oil, &c.

What expense is it a mile upon your coach? I have taken the one hundred miles, and included the day's expenses.

Were you ever a stage proprietor yourself? No.

Then from your own knowledge you can state nothing as to the cost of carrying passengers by a stage coach? No.

Could you, if you were to travel one hundred miles in ten hours, keep up that rate without damage to the machine? Yes, I reckon the work would be done in eight hours, but the stoppages and one thing and another will take up two hours.

Mercurii, 100 *die Augusti*, 1831.

John Farey, esquire, called in; and examined.

Have the goodness to state your profession? I am an engineer.

How long have you been so? It is twenty-five years since I began my studies; I have been much employed by inventors to assist them in bringing forward new inventions of a mechanical nature, and in establishing them as practical businesses, when they have been sufficiently perfect to admit of so doing.

Have you turned your attention to the subject of propelling stage coaches or other carriages, by steam power on common roads, instead of by horses? I have had occasion to prepare specifications of several such inventions for which patents have been taken out, and have in consequence paid a close attention to that subject. I have also been consulted to settle the plans for the practical execution of steam coaches, but I have not directed or superintended any such execution myself. Of the specifications I have prepared, three have been followed up by building coaches, which have actually travelled on common roads; viz. Mr. Gurney's, Mr. Hancock's, and Messrs. Heaton's. I believe those three are the only trials amongst many others which have had so much success as to have been persisted in to the present time. I have examined other steam coaches, but they had no chance of success, and have been abandoned.

Will you state, generally, your opinion as to the probability of this mode of propelling carriages superseding the necessity of using horses? All that has been hitherto done, or which is now doing, in that way, must, I think, be considered as experimental trials. I have no doubt whatever but that a steady perseverance in such trials will lead to the general adoption of steam coaches, and that, at an earlier or later period, according to the activity and intelligence with which an experimental course is conducted; and I am firmly convinced that the perfection which is essential to their successful adoption will never be attained by any other course than that of reiterated trials. The difficulties with which the steam coach inventors are at present contending, are chiefly of a practical nature, which, I think, are not likely to be avoided by any great efforts of genius or invention; but I expect that they may be surmounted one after another by the experience which may be gained by competent mechanicians in a course of practice. I do not look for much more invention as necessary to the establishment of steam coaches; but it is certain that the practice is indispensable. Each of the three inventors I have named has brought his steam coach to that state which renders it a full-sized model for making such experiments as serve to prove the principle of action, and to teach how a better coach may be made the next time, but nothing more. The probability that such next better coach will be sufficiently perfect to answer as a trading business, depends as much upon the natural judgment and acquired skill of each inventor, as upon the qualifications of his present production.

Has the experience which has already been had of steam carriages been such as to enable us to say that it is not merely in theory we have calculated on these carriages? Yes; what has been done by the abovementioned inventors, proves to my satisfaction the practicability of impelling stage coaches by steam on good common roads, in tolerable level parts of the country, without horses, at a speed of eight or ten miles an hour. The steam coaches I have tried, have made very good progress along the road, but have been very deficient in strength, and consequently in permanency of keeping in repair, also in accommodation for passengers and for luggage; for which reasons they are none of them models to proceed upon to build coaches as matter of business. From the complexity of their structures and the multiplicity of pieces of which they are composed, it is impracticable to give them the requisite strength by mere addition of materials, because they would then be too heavy to carry profitable loads as stage coaches. I do not consider that it is now a question of theory, for the practicability I conceive to be proved; but many details of execution, which are necessary to

a successful practice, are yet in a very imperfect state. My view of the subject will be best understood by stating, that I believe an efficient steam carriage might now be made merely to carry despatches, by following the general plan of the best steam coach which has yet been produced, improving the proportions wherever experience has shown them to be faulty, using the very best workmanship and materials, and giving a judicious increase of strength to the various parts which require it, allowing all the weight of a load of passengers and luggage, and of the accommodations for them, in additional strength of materials, so that the total weight of the coach, without any passengers or goods (beyond the people and stores necessary for its own use and one courier,) should be as much as the weight of the previous model containing a full load of passengers and luggage. If three such coaches were constructed, one of them might start every morning at each end of any fair line of road 100 or 120 miles long, and one would arrive every evening at each end of that line in less time than a common stage coach; and I should expect that, after twelve months' perseverance, and after making all the improvements and alterations in the machinery which so much experience would suggest, the double passage ought to be made with as much safety and punctuality, and with much more expedition, than by the mail. The road between London and Bristol might be taken as a suitable line, but I should expect a pair of horses to be provided at every notable hill, to help the steam carriage up it. Such a proposition, it is obvious, offers no inducement to individuals, because it would be all expense without any return; but if it were judiciously done at public expense, I have no doubt but that it would lead to as much improvement in the mode of execution of future coaches as would enable them to be run permanently as stage coaches with profitable loads. The great defect of all the present models, is want of strength to resist the violence to which they are subjected in rapid travelling with a full load; and if that strength were given upon the present construction by the mere addition of materials, they would become too heavy to be efficiently propelled, even if they carried no load in them.

Have you seen the last coaches of Mr. Gurney and of Mr. Hancock? I have not minutely examined the last addition of Mr. Gurney's carriage, but have met it several times on the roads in my neighborhood, as I have also that of Mr. Hancock; and I have travelled in the latter; but he has enlarged the cylinders of his engine since I have gone in it.

You have seen Mr. Gurney's original boilers; he states that he has altered very little in the form of them? Yes; I was well acquainted with the construction and performance of all that Mr. Gurney had attained at the time when I specified his patent, three years ago; and I understand generally the alterations he has since made, though I have not made trial of any of his more recent coaches; the principal change is in separating the engine and machinery from the carriage which is to convey the passengers, so that there are two four-wheeled carriages, one drawing the other after it. This change involves no very great alteration in the machinery, which I understand, is nearly the same as it was; but the impelling carriage in which it is placed is very much lightened by transferring all the passengers to the additional carriage which is drawn. Mr. Hancock continues to follow the original plan of carrying the passengers in the same four-wheeled carriage with the engine.

As far as your experience has gone, which plan of steam carriage do you think will hereafter be most generally resorted to, that of an engine carriage

drawing after it another carriage containing the passengers, or of conveying the passengers in the carriage in which the machinery is placed? I have not had experience in drawing by two carriages, except by the analogy of what is done on railways, and hence I feel some difficulty in speaking positively upon that point. There are advantages and disadvantages to be considered in both modes, but all the mechanical considerations incline to one side, viz. to place the engines in the same carriage with the passengers. That plan will certainly be lighter than when two separate carriages are used, and also the weight will be laid on those wheels which are turned by the engines, as it should be, to give them a firmer adherence to the road; also one carriage will steer and turn much better than two, and will go safer down hill, and will be cheaper to build and to work.

By that means great weight is saved? Yes; perhaps one-third is saved in exerting an equal power. In stating my opinion of the probability of a profitable result, after twelve months' trial of three coaches to run regularly two hundred miles every day, with despatches only, I contemplated that the engines and passengers would be ultimately in one carriage, because that plan has a most decided mechanical advantage in making progress along the road, and also in facility of steerage, and safety in going down hill, and fewer servants are required to manage one carriage than two. On the other hand, all the constructions that have yet been tried with one carriage, subject the passengers to more or less occasional annoyance from heat and noise, smoke and dust, and there is still an apprehension of danger from the boiler: hence passengers will invariably prefer to go in a separate carriage to be drawn by the engine-carriage; that mode also offers a facility of changing the engine for another, or for post horses, in case it gets deranged, because the change may be made without unloading, and discomposing the passengers. For common stage coaches these are strong motives to use a separate carriage, and if it can be brought to bear in comparison with horses, that mode will probably be most generally adopted by the influence of the passengers, although the other mode will inevitably perform the best and attain the greatest speed of travelling.

Taking the two machines of Mr. Gurney and Mr. Hancock in their present state, do you think them entirely free from defects likely to prove dangerous to travellers? I do not think the danger is at all considerable in either Mr. Gurney's or Mr. Hancock's: there are dangers in all travelling; but I do not think the amount of danger will be at all increased by substituting steam for horses, according to either of those plans.

The question refers to the peculiar danger from the nature of the propelling power? I am not inclined to think that there is any peculiar danger which would be incurred by the change; and if the engines and passengers are not on the same carriage, I think the ordinary danger would, on the whole, be diminished.

The question is with reference to the relative danger of travelling ten miles an hour when drawn by horses, and when propelled by steam at the same rate? The danger of being run away with and overturned is greatly diminished in a steam coach. It is very difficult to control four such horses as can draw a heavy stage coach ten miles an hour in case they are frightened, or choose to run away, and for such quick travelling they must be kept in that state of courage that they are always inclined for running away, particularly down hill, and at sharp turns in the road. The steam power has very little corresponding danger, being perfectly controllable, and capable of exerting its power in reverse, to retard in going down hill; it must be careless-

ness that would occasion the overturning of a steam carriage, which carries the passengers in the same carriage with the engines. The distinct carriage I consider to be much less controllable in turning corners and going down hill, but yet far more so than horses. The chance of breaking down has hitherto been considerable, but it will not be more than usual in stage coaches when the work is truly proportioned and properly executed. The risk of explosion of the boilers is the only new cause of danger, and that I consider not equivalent to the danger from the horses. There have been, for several years past, a number of locomotive engines in constant use on railways, all of them having large high pressure boilers, very much more dangerous than Mr. Gurney's or Mr. Hancock's, whether we consider the probability of explosion, or the consequence likely to follow an explosion, because, being of large diameters, they are less capable of sustaining the internal pressure of the steam; and also they contain a large stock of confined steam and hot water. The instances of explosion among those locomotive engines have been very rare indeed.

Have you seen Mr. Hancock's last improvement? Yes; I consider Mr. Hancock's boiler to be much better for steam coaches than any other which has been proposed or tried.

If that boiler were to explode it is understood that there would be no danger at all? It is very difficult to foresee that; at the same time, the risk of explosion in Mr. Hancock's boiler is certainly very much less than in the locomotive boilers which are in constant use on a large scale on railways, and where we have proof that the extent of the danger is very small.

Do you think his boiler might explode without the passengers knowing any thing about it? The metal plates of which the boiler is composed will burn through by the continuance of the action of the fire, and may crack or open so as to let the steam or water out of the boiler and disable the coach from proceeding, but that is hardly to be called an explosion; no one would be hurt. The crack which lets out the hot water is sure to throw it into the fire in that case, and not on the passengers.

You consider the danger to passengers by the chance of bursting of a boiler as not equivalent to the danger of horses running away? It is not equivalent, in my opinion; the probability of a coach being overturned by the horses is far greater than that of a boiler bursting, and when either accident does occur, the probable extent of mischief from an overturn in which all the the passengers must participate, is much greater than could be expected from the bursting of a boiler, which must always be kept at a considerable distance from the passengers on account of the heat.

Supposing either Mr. Hancock's or Mr. Gurney's boiler were to burst; in the one case the boiler being in a separate carriage, and in the other, the boiler being at considerable distance behind the passengers, what danger do you think could arise to the passengers from the bursting of the boiler? There is very little difference between the two cases; the separate carriage obviates any apprehension that passengers could entertain from the danger of explosion, and will therefore be preferred by most passengers, but for myself I do not rate that risk so high as to be induced to encounter the complexity of the two carriages, and to forego some of that new security which steam power offers by its controllability in descending hills and turning corners, compared with horses; and which circumstance, as I have before stated, I think the plan of one carriage is much to be preferred, and probably the other objections of heat and noise and dust may be overcome by some new means,

which have not yet been shown. In Mr. Hancock's carriage the boiler is quite behind, and away from the passengers, so that they are out of danger, if there is any, and are not materially annoyed by heat or smoke and dust, except at times when the wind brings it forward, and that rarely happens when the coach is moving.

Is not the danger attendant on the bursting the boiler greatly diminished by the subdivision of its internal capacity into tubes or small and flattened chambers? Unquestionably, until the danger of explosion has become exceedingly small; but the great difficulty of boilers for steam coaches is, that the liability to burn through the plates has been increased by that expedient for ensuring safety; and the progress of the invention has been impeded between those two difficulties in a greater degree than from any other circumstance. It was a desideratum for a long time to contrive a boiler, which, being made of such thin metal as would not render it too heavy, should have sufficient strength to retain high pressure steam without danger of bursting; also that it should expose a sufficient external surface of metal to the fire and flame, and of internal surface to the contained water, to enable the required quantity of steam to be produced from such a small body of water as could be carried on account of the weight: both these conditions were fulfilled by subdividing the contained water into small tubes or into flat chambers, which expose a great surface in proportion to their internal capacity, and admit of being made strong with thin metal; but there is also another condition which is rather incompatible with the two former, viz. that there shall be such a very free communication between the interior capacities of all the tubes or narrow spaces, as will combine them all into one capacity, and permit the contained water to run from one to another, and also permit the steam, which is generated in innumerable small bubbles within the narrow spaces, to get freely away from them, to go to the engines without accumulating and collecting into such large bubbles as would occupy the spaces and displace or drive out the water before them; for, if that effect takes place, it produces three great evils; the water boils over into the engines along with the steam, and is wasted, and the thin metal which remains exposed at the outside to the fire, becomes burning hot in an instant, after the water is so driven away from the internal surface, and the further production of steam is suspended, so long as the water continues absent. If such displacement of the water takes place frequently, and in many of the narrow spaces at once, the boiler will not produce its proper quantity of steam, and the thin metal will soon be destroyed by the fire and burned through.

Have you seen Mr. Hancock's boiler? Yes; I have had many trials of it; and I am well acquainted with Mr. Gurney's. The former uses flat chambers of thin iron plate standing edgeways upwards over the fire in parallel vertical planes; the latter uses small tubes (such as gun barrels are made of,) to contain the water, the fire being applied on the outsides of the tubes. In Mr. Gurney's boiler I think the subdivision of the water into small spaces is carried too far, because the steam cannot get freely away, out of such small tubes as he uses (and they are also of great length) without displacing much of water which ought always to be contained within them. By an ingenious arrangement of connecting pipes and vessels which he called separators, he collects all the water which is so displaced along with the steam, and returns it again into the lower ends of the same tubes, and thus avoids the evil of water boiling over into the engines; but that makes only a partial remedy for the diminished production of steam, which is attendant on the absence of the water from

the heated tubes, and the still greater mischief of burning and destroying the metal. Hence the evil of burning out the tubes is very great. Also his separators hold a considerable weight of water, from which no steam is generated; and they require to be heavy in metal, to render them quite safe and strong. Mr. Hancock has taken the middle course in subdividing the water in his boiler, having all that can be required for safety, and the weight I believe, on the whole, to be less than that of any other boiler which will produce the same power of steam; for, owing to the freedom with which the steam can get away in bubbles from the water, without carrying water with it, the surface of the heated metal is never left without water. Hence a greater effect of boiling is attained from a given surface of metal and body of contained water, and that with a much greater durability of the metal plates, than I think will ever be obtained with small tubes.

Do you think there is a danger of such an explosion as could do injury from the mode in which Mr. Hancock's boilers are constructed? That danger I hold to be very slight; the metal of Mr. Hancock's chambers will burn through in time, the same as that of Mr. Gurney's tubes will do, but not so soon. I think, taking the thickness of metal to be the same in both cases, no injury will be done by such burning through. The flat chambers in Mr. Hancock's boiler are very judiciously combined, and are secured against bursting by causing the pressure which tends to burst each one open, to be counteracted by the corresponding pressure of the neighboring chamber, and the outside chambers are secured by six bolts of prodigious strength, which pass through all the chambers, and unite them all together so firmly that I see no probability of an explosion. Mr. Gurney's vessels, called separators, are secured by hoops round them, and, being of a small size, may be made very safe. Hence I think the two boilers may be put on a par as to their security; but there is a decided preference in my opinion of Mr. Hancock's form of subdividing the water and steam compartments, which I believe is carried too far in Mr. Gurney's tubes whereby the water, included within the several tubes, cannot make way to allow the bubbles of steam to pass by it. This is owing to the great length and the small bore of the tubes; and they are so isolated one from another, that the water within them is not able to act as a common stock of water, or to keep all the interior surfaces of the metal tubes thoroughly supplied with water: thence, there is a deficient production of steam and an unnecessary destruction of metal.

Are you aware that, in Mr. Hancock's carriage, the waste steam which is discharged from the engines after having performed its office, is thrown into the fireplace, and makes its escape upwards along with the flame, smoke and heated air, and gas, which ascend from the fire to act on the boiler?—That is the way in which he gets rid of the waste steam which the engines discharge, and I understand that he thereby avoids the puffing noise and appearance of steam which is common with high-pressure engines. Mr. Hancock blows the fire with a current of air produced by a revolving fanner, which is turned rapidly round by the engines, and therefore he requires no tall chimney to produce a draft. Mr. Gurney formerly used a singular fanner to blow the fire, and also a chimney of some height; but I understand he has lately laid it aside, and adopted the plan of carrying the waste steam which has passed through the engines into the bottom of the upright chimney, and there discharging that steam through a contracted orifice in a vertical jet, which, by rising upwards with great velocity in the centre of the chimney tube, gives a vast increase to the draft of heated air and smoke in

the chimney tube, without any great height being necessary; and this plan occasions a most active current of fresh air to pass up through the fire, and urge the combustion. This is a most important improvement in locomotive engines, which has been introduced by Mr. Stephenson into his engines on the Liverpool and Manchester railway, and being there combined with an improved boiler, it has been one of the great causes of the brilliant success of that undertaking. I believe the same plan will be indispensable to the complete success of steam carriages; for chimneys cannot be used high enough to obtain a draft, and blowing the fire is a very troublesome affair. I fear Mr. Stephenson's plan would occasion more noise than is allowable on common roads; but that may perhaps be avoided or diminished by some new expedient.

Do you think any danger would arise from the waste steam being discharged over a large mass of fire on Mr. Hancock's plan? Not the least danger; all the waste steam which blows off at the safety-valve, and which the engines do not require, is got rid of in the same way; but I expect Mr. Hancock does not help the combustion of the fuel by thus mixing the waste steam with the flame before it acts against the boiler. Mr. Stephenson's improvement, which Mr. Gurney has adopted, is to discharge all the waste steam into the bottom of the upright chimney with a violent vertical jet, in order to accelerate the draft up the chimney. The waste steam, therefore, is mixed with the smoke and gas, after the smoke had ceased to act on the boiler. The waste steam was very commonly discharged into the bottom of the chimney, in Trevethick's high pressure engines, many years ago, in order to mix with the smoke ascending in the chimney, and thus get rid of the waste steam; it improved the draft in that way, by rendering the smoke more buoyant, but only in a slight degree; but the waste steam was not discharged through a contracted orifice to give it velocity, nor was it directed upwards as is now done by Mr. Stephenson, and that vertical jet of steam in the centre of the chimney, gives such an intensity of draft through the fire as was never procured before, and, with the further advantage, that the rapidity of draft so produced, increases whenever the engines work faster, and discharge more steam, just in proportion as the demand for fire and steam increases by that working faster.

Is there any noise occasioned in that way?—Yes; but the sound is directed upwards by the chimney, and is not much heard in the locomotive engines on the railway when they are in the open air, but when they pass under the bridges, the sound is reverberated down again by the arch, and then it sounds very loud. The noise is no great consequence there, and no particular pains have been taken to avoid it. The metal pipe of the chimney has something of the effect of an organ-pipe or trumpet, but it is probable the sound might be deadened.

Will the burning out of the plates of Mr. Hancock's boiler, that you spoke of, be attended with risk of explosion of the whole boiler, or only of the smaller divisions of the boiler?—It will be attended with no violence which could be called an explosion, nor with any danger whatever, but only with the inconvenience of disabling the carriage until the ruptured chamber is replaced by another. The rupture or crack of the metal plate at the burned place, would let out the water and steam very gradually into the fire, and probably extinguish it. All steam boilers burn out in that manner sooner or later. The different chambers of Mr. Hancock's boiler are kept together by six very strong bolts, which pass through them all, and which are

quite protected from the action of the fire; to burst the boiler those bolts must give way altogether, and there is no adequate force to produce any such effect.

Are you acquainted with the construction of the new steam carriage which started this week from Gloucester to Cheltenham?—I am not, further than that is on Mr. Gurney's plan.

Apprehension has been felt that these steam coaches will be found to give great annoyance to travellers passing them on the public roads, from smoke and the peculiar noise from letting off the steam; do you apprehend such results will take place?—I do not anticipate any great annoyance will result to travellers in other carriages. I have passed Mr. Hancock's on the road several times and Mr. Gurney's also, and have travelled in them often; horses take a little notice of them when in motion, but not much, and very soon become accustomed to them. I once met Mr. Hancock going very quick along the New road, and drew up to see him pass; I had no difficulty whatever in making my pony stand, though rather a spirited one. Mr. Hancock did not observe me; and as I wished to go with him, I turned and drove after him, and after a race to overtake him, I had no difficulty in drawing alongside of his steam carriage for a good way in order to speak to him, and get him to stop for me. The emission of hot air was very sensible, when following close alongside of the boiler at the hinder end of the carriage, but I did not observe any puffing of steam.

Do you think that whatever annoyance exists in the present steam coaches may be removed by the improvement of the carriage, and particularly the appearance of the carriage?—Certainly their appearance may be improved; they are most unsightly now. The general question of farther improvements in steam coaches depends upon the general mechanical skill and judgment of the mechanicians who turn their attention to the subject, and the peculiar experience they acquire in this particular branch of mechanics, by continually practising and exercising with steam carriages, on roads of all kinds in all weathers, to find out their defects, and how to remedy them; and what is the best mode of management; also, by building new and better carriages as soon as they have learned what will be better than the present ones. But all this must be at a great pecuniary loss, and some further encouragement must be held out in order to induce the more skilful mechanicians to embark in such a pursuit; for, at present, it is by no means an object of attention to our best and most competent engineers, because they know they would only throw away their money and time by undertakiug steam coaches, even if they were to succeed ever so completely. The patentees are a different class of men; they are the inventors, who have first organized and arranged the combination of machinery which is to be used; and according to law, they have acquired a legal property in those peculiar combinations which they have discovered, that has been their encouragement and stimulus to exertion; but the terms of their patent rights will be very likely to expire before their inventions come into use to such an extent as will repay them their previous costs with any profit thereon; and also, with the present defective state of the law on the subject of patents, they will be unusually lucky if they are able to make good their patents at law, in case their rights are contested. The patentees are not experienced mechanicians or engineers, and have had to learn the business of engine-making and of coach-making as they went on; and a great deal of the deficiency of the present steam coaches has arisen from the circumstance, that th ey have been

made by persons who were not at that time qualified to execute either a common coach or a common steam engine; but they have acquired more skill, now, and we may expect more finished productions from them in future. There is no mechanician, of the class of those who will be ultimately employed to make the engines and machinery of steam coaches when they do come into use (and who alone can give that perfection of design, proportion and execution, which is essential to their coming into use,) who will have any thing to do with them now; not so much from any doubts that they would not be able to succeed in perfecting them, as from a conviction that the expense of attaining success would be greater than would be repaid by any advantage they could afterwards derive from making such machines, in open competition with every other mechanician who chose to copy after their model when perfected; for that perfection of design, proportion, and execution, in which steam coaches are now wanting, though very laborious and expensive of attainment, would not be grounds for exclusive privileges under the existing law of patents. The patents to the first inventors are the only ones which are professed to be recognised by law, though in effect they can scarcely ever be maintained at law. That is a very important point for the consideration of the committee, and one which deserves great attention. As the law of property in inventions now stands, when a new invention is advanced to such a stage that it may be considered to be tolerably perfect as an invention, no further exclusive privilege can be maintained to compensate for the skill, labor and expense, which must be incurred to find out true proportions, dimensions, weights and strength, which are essential to bring it to bear as a practical business. The law professes to give the whole to the first inventor, although he may have only laid the foundation on which another has raised the superstructure; and if, as usually happens, the claim of the first inventor is set aside, from technical informality in his title-deeds, and also when his term expires, the whole superstructure lapses, to the public. For these reasons, those who are the most competent to the task of giving the finishing touches of practical utility to great inventions, are kept back by being aware that they shall not be repaid. Under such circumstances, a defect of judgment would be proved *a priori* against any one who might commence such an unpromising pursuit, and that want of judgment which could permit a man to overlook the pecuniary considerations, would not be favorable to his success as a mechanician, in giving that precision of form and dimensions, and that practical utility, to an invention which requires an exercise of the cool judgment resulting from experience, rather than of the genius depending upon original thought.

You do not consider the inconveniences of the present steam coaches to be inseparable from the invention? Certainly not; but I do not think that any of the individuals at present engaged in the pursuit are the most competent persons who could be chosen to overcome the remaining difficulties, being inventors, who have almost completed their parts of the task, and not experienced practical engineers, into whose hands the affair of building the next steam coaches ought now to pass, under the general direction and advice of those inventors. If the building of steam coaches is continued in their hands, they will only advance towards perfection of proportion and execution by slow degrees, as the patentees acquire that general skill as engineers and mechanists which is already possessed by professional engineers.

You think that the machinery may be improved by better machanists? I have not the least doubt of it; and yet those mechanists are not the proper

men of genius to have invented what has been hitherto done by the patentees.

Apprehensions have been felt by trustees and surveyors of roads that steam carriages are more injurious to roads than carriages of equal weights drawn by horses; what is your opinion upon that point? I should not apprehend that the present coaches are injurious in a greater degree than other carriages of equal weights; and when steam coaches are really brought to bear, I think they will be much less so than any carriage at present in use taking horses and the carriage they draw against engines and the carriage they impel, at weight for weight. All my observation upon steam carriages has led me to believe that they do no particular harm to the road. I could never perceive any peculiar marks that they left in their tracks, and, an examination of the iron tire on the edges of the wheels of Mr. Hancock's carriage, shows evidently that no slipping takes place on the surface of the road; and that fact is proved to a certainty by other observations on the working of that carriage. It will be a long time before a sufficient number of steam carriages travel over any road to bring their effect on the materials to the test of experience; but, on general principles, I have no hesitation whatever in stating my opinion that they never will answer as long as they do injure the roads any more than the fair wear occasioned by the wheels of other carriages of the same weight; for any injury they might do to the road must be by slipping of their wheels on the road, which would be a waste of the power of their engines, and hitherto they have had no power to spare; or, if their wheels are too narrow, and they cut deep into the road, the power of the engines will be wasted. If they are to be efficiently advanced, the whole power must be fairly exerted in advancing them forwards along the road, without turning their wheels in vain on the road, or cutting ruts in the road. I am confident that, if the wheels slip at all on the the roads so as to lose motion, or if they penetrate so as to make ruts, those coaches will not answer, and the defects must be remedied, or the coaches must be given up. I do not mean to affirm whether the present steam coaches which draw other carriages after them do or do not slip on the road, because I have not examined them; but I am of opinion that, for the ultimate successful application of steam power, the carriages must be so constructed that they will do less injury to the roads than carriages drawn by horses; and whenever steam coaches become common, I think the roads will be most materially benefitted by the change.

Supposing the total weight of a stage or mail coach, drawn by four horses at ten miles an hour, to be two tons, and the weight of the four horses to be two tons, what proportion of the wear of a Macadam road would you expect to be occasioned by the wheels of the coach, supposing them to be the usual breadth of stage coach wheels, and what would be the wear by the horses' feet? It is impossible to fix an accurate proportion for such a question as that; but I have no doubt but that, weight for weight, horses' feet do far more injury to a road than the wheels of a carriage, and particularly so at quick speeds, because wheels have a rolling action on the materials of the road, tending to consolidate, and the horses' feet have a scraping and digging action, tending to tear up the materials. One test of the wear by horses' feet will be in the wear of towing-paths for canals, and the railway roads where horses are employed. In either of those cases, the number of horses which pass along is so small, that no turnpike roads afford any ex

ample of comparison, and yet the wear of towing and railway paths is found to be considerable. The rapid wear of horses' shoes is another test.

It has been stated by a previous witness, that the proportion of the wear of a Macadam road, under such circumstances, would be about two-thirds by the horses, and one-third by the carriage; should you think that a fair approximation to the truth? I have no means of judging with such precision, but I have no doubt whatever that, in the case above supposed, the wear by the horses' feet would be much greater than the wear by the wheels; for, independently of the difference of the action, as before stated, the rapidity of the blows wherewith the horses strike down their feet, in stepping quickly, wears the road, and they keep their feet pressing on the same spot for a sensible time afterwards, which must have a far greater effect on the materials, to wear and loosen them, than the comparatively progressive rolling of the wheels over the road, because the latter remain only an imperceptibly short space of time on the same spot, and have a consolidating action.

May you take the wear of horses' shoes, in proportion to that of the tire of the wheels, as a fair test of the proportionate wear of the road by each? No, by no means; because the pressure which the wheels exert, and which wears away the tire, is, under certain conditions, very beneficial to the road; whereas the pressure occasioned by the horses' feet is in all cases pernicious. On a gravelled road, which is not yet consolidated, the rolling action which causes the wear of the tire of wheels produces a great improvement of the road, when the treading action, which causes an equal wear of horses' shoes, does nothing but mischief. The harder and more solid the road becomes, the less this may be apparent, because the wear of the road becomes so imperceptible; nevertheless, I think the proportion of less wear by wheels than by horses' shoes, will still hold true.

What is the average width of the tire of the wheels of steam carriages you have tried? Mr. Hancock's wheels are two inches and three inches broad; in Mr. Gurney's carriage, when he carried the load along with the engines, the wheels were two inches and a half broad; but I understand he has widened them since he has altered his system of drawing a separate carriage, which is to be expected as a necessary consequence of the alteration.

Do you think the machine would act with less advantage if the wheels were wider? That depends entirely upon the weight resting upon the wheels, and the sort of roads they are to run upon. I think it would be better for those individual carriages to use broader wheels than they had.

If the tire of Mr. Hancock's were six inches broad, would it be an advantage or a disadvantage? I think six inches would be too wide for that description of carriage; about four inches I should think a suitable width for his wheels. Mr. Hancock's carriage is so arranged, that a greater proportion of the whole weight of the carriage is thrown upon the hinder wheels, to one or both of which the power of the engines is applied, than upon the fore wheels: that I think is very judicious, because it ensures such an effectual adhesion of the hind wheels to the road, that no slipping can take place. The breadth of the wheels must be so proportioned to the pressure that they exert on the road, that they will not indent or press in, to leave deep marks behind them. The actual breadth that will be suitable to any given weight will depend upon the hardness of the materials of

which the road is made, and roads differ very much in that respect. I think that in all cases the breadth of wheels which will enable the carriage to make the best progress, will be that which will do the least injury to the road, for it will be that which will occasion no disturbance of the stones after they have been consolidated, but will only wear away their upper surfaces, and the iron of the tire.

You have stated that you think the bringing of these machines to perfection is retarded, because there is not a sufficient prospect of encouragement, and that steam coaches are therefore confined to the hands of persons who have not the same skill in practical mechanics as others, who would undertake the subject if adequate encouragement were offered; can you point out any mode by which that encouragement could be given?—Nothing could do it so effectually as offering a handsome parliamentary reward for the attainment of some specified performance, such as keeping a steam coach for passengers regularly plying on some suitable road for two years, during which it should not have failed to arrive by steam more than some specified number of times, and within a certain number of hours of lost time from the time-bill of the mail on the same road. Suppose this were done between London and Bistol, for a reward of 10,000 *l.* it would cost the public nothing if it were not accomplished, and the establishment of that one coach to carry the mail would be worth the money to the public whenever it was accomplished; or between London and Holyhead would be still more important, but that would require 20,000 *l.* reward. Another plan of more immediate application would be to offer a bounty of a fair price per mile for carrying despatches by steam (as I suggested before) whenever they arrived in a specified time; the price should be sufficient to pay expenses. That would, I think, be the best course, because I believe it would be undertaken at once by individuals, provided that no stipulations were made either for or against carrying passengers or goods. They would be sure to carry passengers and goods as soon as they could; for their own profit; and it might be stipulated, that after any coach had earned a certain sum in bounty, it should not be entitled to more. The effect of such public rewards has been very striking in the case of the invention of means of ascertaining the longitude at sea. Another way would be, instead of money, to give exclusive privileges for a term to any persons who should first succeed in establishing steam coaches on specified roads, under specified conditions of performance; or a society offering a premium, as was done in the case of steam navigation to India, would have a good effect: as was also shown in the case of the locomotive steam carriages on the railway between Liverpool and Manchester. There a most inadequate premium (only 500*l*,) brought the invention forward more than ten following years of desultory and unencouraged attempts would have done.

You think those means would produce a great effect?—I have no doubt of it; an important result may often be within a moderate sum of attainment, and yet a prudent man will not set about it. It will be certain to cost 1,000 *l.* and a year's hard labor of an engineer, whose time is worth 500 *l.* more, to make a new steam carriage in a proper manner and bring it to bear as a business, supposing that its performance turns out as near to previous calculation, according to the experimental coaches now in existence, as can be expected, and that no radical alterations require to be afterwards made in it. After succeeding in the attempt, he must expect to make copies of it on the same terms as other makers, who would examine one of the first coaches he sends

out, and copy it with very little trouble. The operations of competent mechanicians in making first machines of new invention, and bringing them to perfection in all their details, are necessarily more expensive than those of first inventors, who execute their experimental machines in a slovenly manner with cheap workmanship only as experiments; but when those experiments have been gone through, an extreme soundness and accuracy of workmanship is the only chance of attaining success in the machines which are sent out for real business. For want of experience to direct the mechanician as to the right form, dimensions and weight of each piece of his machine, it often happens that, after having made a piece of expensive work, it will prove too slight or too heavy when set to work, and he may have to make it over again as expensively. The copyists, who will afterwards come into competition with him when his machine is brought to bear, will have no such difficulties.

You conceive that a grant of public money as a premium would call forth the necessary degree of skill?—I have no doubt of it; we have had very few instances of invention being stimulated by the offer of public reward; but the instances, ascertaining the longitude is a most brilliant example. The facility and accuracy with which the longitude is now determined at sea, is the result of one of the greatest efforts of human genius and preseverance. The stimulus of reward has occasioned both modes of it be perfected, viz. by astronomical observations and by time-keepers. We should very soon have steam carriages brought into full use if such a reward were offered.

Have you ever ascertained the duty or performance of work done in respect to the fuel consumed by locomotive engines?—They vary so greatly, that it is difficult to make a statement. The common locomotive engines which have been used for several years to draw coal wagons on railways, have remained without material improvement for a long time, and their performance is very low, being only equal to raising about four millions pounds weight one foot high by the consumption of a bushel of coals, their boilers evaporating about four cubic feet and a half of water into steam with each bushel of coals. Such engines exert six to eight-horse power. Mr. Stephenson's new quick-going engines on the Liverpool and Manchester railway are more improved in duty, and are in a progressive course of improvement; but as they burn coke instead of coal, the established mode of computation is inapplicable. Mr. Stephenson's small engine, called the Rocket, which gained the prize of 500 *l.* offered by the Liverpool and Manchester railway company, and which was the model for succeeding engines, exerted about six horse power during that trial, and burned 177 lbs. of coke per hour, which is at the rate of about five millions and a half pounds weight, raised one foot high by the consumption of 84 lbs. of coal; but they have greatly reduced the consumption of fuel in the succeeding engines on that railway, owing to enclosing the cylinders of the engines within the lower part of the chimney, were they are kept very hot, and an increased effect has been given to the fire by blowing the waste steam upwards through the chimney, as I stated before. In the Rocket they were just beginning to be aware of the value of that expedient for animating the fire, and it was done in a degree, but it has been since done more completely.

Do you know how near any part of the railroad between Manchester and Liverpool runs to the common road?—I cannot say; in passing along the railway, I do not recollect seeing the turnpike road, except crossing it several times.

The noise made by the engines used on the railway is much greater than by the steam coaches, is it not? Yes; Mr. Hancock's coach makes less noise than any of Mr. Stephenson's engines; but the power exerted by the latter is much greater than by Mr. Hancock's engines. The quick-travelling carriages on the Manchester and Liverpool railway, when drawn by the last improved engines, are extremely easy in their motion.

Is it your opinion, that a road would suffer less injury from the fore and hind wheels of a steam carriage following each other, in the same tracks on the road, than if they run on different tracks?—That depends upon what kind of action the wheels exert on the road; if they cut it up and disturb the materials, by pressing down some stones so deep as to displace other stones sideways, and cause them to rise up at the sides of the track, then it is best not to allow such wheels to cut the road twice in the same places; but if the fore wheels roll the road smooth on the surface, and consolidate, without disturbing the materials; that is, if they only press down the stones over which they pass as much as will produce a close contact, but not so much as to displace the neighboring stones laterally, then I think the hinder wheels should follow in the tracks of the fore wheels; certainly that is best for the carriage; and I believe it will be found that it makes but little difference to a good hard road whether the four wheels of a carriage follow in the same track or not, provided that the wheels are not loaded so as to indent deep into the solid materials of the road. All carriages ought to have their wheels of such a breadth that they will not leave any material indentations in the road. They should rather consolidate the materials than break them up. If the fore wheels are only so much loaded, in proportion to their breadth and to the hardness of the road materials, that they will consolidate the materials over which they have passed, then I think it is quite as well for the road and much easier for the carriage, that the hind wheels should follow in the tracks of the four wheels. The loading of the carriage may be so arranged that the principal weight will be borne on the hind wheels, and the fore wheels may (by a suitable apportionment of breadth) be qualified to consolidate the road in their tracks, and thus prepare the way for the passage of the hind wheels, with the least wear of the road and the greatest ease to the carriage. It is quite as much the interest of the proprietors of carriages, as of the road trusts, that the roads should not be cut up by too narrow wheels, for it is always at the expense of horse-labor that the road is thus injured, independently of the evil of having a worse road to travel over the next time. If the wheels are too narrow for the load upon them, and the road materials soft, so that the wheels do print tracks in the road, that evil will be greater, if the hind wheels follow the fore wheels than if they run in new paths; but it is better to remove the evil, by using broader wheels or less load, or harder road materials, and to run the wheels in the same tracks; because the resistance to a carriage is, in all cases, increased by running the wheels in different tracks, and that with little or no benefit to the road; particularly, when the road is covered with mud and wet dirt or snow. The above observations apply to all four wheeled carriages, whether they are drawn by horses or impelled by steam; but, in common carriages, the horses' feet tend to dig up the road. I think the steam carriages will, when perfected, be free from that objection, and that they have a greater claim to be allowed to run their wheels in the same tracks than other carriages.

Were you ever in Mr. Hancock's carriage, when travelling? Yes; I have

ridden on it; but he has put in larger cylinders since I went with him the last time, and I understand makes better progress now. I have examined all his present machinery in detail, and think it very judiciously planned.

Did you find that it frightened horses, or annoyed passengers? I have stated before, that I found horses were not frightened; but every one must judge for himself of the degree of annoyance he experiences. Persons who are accustomed to travel in luxurious private carriages, would find many annoyances in a common stage coach, which others would consider as excellent travelling. I am so accustomed to machinery, and to stage coach travelling and to steamboats, that I am not liable to be annoyed thereby; and I found riding in Mr. Hancock's carriage to be exceedingly like travelling in a stage coach. I heard no complaints by passengers. I believe he has never found any difficulty in getting passengers, since he has run for hire. Persons are reported to be annoyed by the smell of hot grease, in the steam coaches on the Cheltenham road; I can only say, that I never observed such a smell in Mr. Hancock's carriage. If there are any real annoyances to the passengers in particular steam coaches, they will work their own cure in a short time, either by the proprietors finding out remedies, or else giving up their coaches, as they must do if they are not rendered agreeable to the passengers. The only question that deserves attention, is, whether there is any danger to psssengers, or any serious annoyance to other persons not passengers.

Did you observe any horses or carriages passing his carriage? Yes, I have always passed through crowds of horses and carriages with all the steam coaches I have tried; there is so much curiosity excited by the novelty of a steam coach in motion, that all the horses on the road are drawn up to get a sight of it, and many are turned to follow after it. I have observed that some horses take very little notice of the steam coach; others are a little startled, but I never saw any difficulty which the reins could not control with the greatest ease. Horses are easily alarmed at any thing unusual, but they very soon become accustomed to any thing, as is shown by the readiness with which horses can be brought to endure discharges of fire-arms and of artillery. A patent was taken out some years ago for what was called a travelling Advertiser; it was a small four-wheeled carriage, supporting an enormous octagonal tower, which was stuck all over the outside with printed bills for advertisements. It was drawn very slowly through the streets by one horse, and had a most unusual appearance: this machine was indicted as a nuisance because it frightened horses.

Have you never observed horses to shy at a stage coach when heavily laden? I have observed horses to be alarmed at the enormous bulk which some of the vans carry at times at a greet height above ground. Horses are the most timid animals to encounter every thing that they are not accustomed to, and the most courageous animals to encounter every thing that they are accustomed to, even when really terrific, such as discharges of fire-arms.

Had you occasion to turn any sharp corners when in Mr. Hancock's carriage? Yes, many; the yard of his premises is exceedingly narrow and inconvenient to turn into and out from, but it is done with ease by the steam coach; but the same place would not do at all for a coach and four horses to put up at.

Going at what speed can you turn round a sharp corner without any danger? I do not remember turning with any considerable speed, nor should it ever be attempted with any carriage if it can be avoided, and there can be

no pretence or necessity for going quick when turning a steam coach, as its power is quite controllable, in which respect it has a great advantage over a common carriage; for four horses at the moment of turning, are very little under the control of the reins, particularly the leaders, and it depends upon their good will whether they choose to go slow or go quick when turning. In a steam carriage, the conductor has such a perfect control of the power, that he can never fail in checking the speed at the moment of turning. I observed that Mr. Hancock's carriage is steered with the greatest ease; and will turn round in a very short space: I have seen him turn round in the new road to return without backing the carriage at all, although he was in the middle of the road when he began to turn.

If you had turned a sharp corner, could you have stopped immediately on meeting a carriage? Yes; the power of stoppage is most remarkable: that is one of the great advantages of a steam coach. I have steered Mr. Hancock's carriage myself, and found it to be most completely under control.

The carriage may he turned in the smallest space that the wheels will permit it to go round in? Yes, in a much smaller space than a carriage with horses can turn, because it is so much shorter in the total length, and the power being completely under control, there is no danger in turning quite short; whereas no prudent driver will turn a four-horse coach round in a road, without the guard getting down and holding the leaders' heads; for they are not sufficiently under the control of the reins in turning to do it with safety.

Did you ever see a steam carriage going down a hill? Yes, down the hill of the new road at Islington; and it was done with more safety than with any carriage with four horses; but I do not contemplate the descent of steam coaches down very steep hills, for that supposes their getting up such hills, which is not likely to be accomplished soon, and the present coaches seem to me to be only fit for our most improved lines of roads, where all very steep hills have been reduced to moderate slopes.

Have you turned your attention particularly to the subject of going up steep hills, and what ascent do you think can be surmounted? In forming my opinion of the probability that steam carriages will be brought to bear, I could not overlook the circumstance that they would have to go up and down hills; but most of our great lines of roads are now so improved, that what were formerly called steep hills are not very numerous or frequent; but wherever they do occur, I propose to give the steam coach the assistance of a pair of post-horses in aid of its own power. In going down hill, steam coaches are very safe, because the whole power can be effectually exerted to retard or resist the turning of the wheels.

Mr. Gurney's steam coach has gone up Highgate hill without horses? Yes, but I understood that it was broken in pieces in coming down again. My objection to attempting to make a steam coach go up a steep hill, in the present state of our knowledge, is, that it requires to have a great strength, and consequent weight of machinery to have a sufficient power to do so with safety, and which weight is a useless incumbrance and impediment to progression at all other times. The question is, whether all the machinery of a steam carriage should be made twice as strong and heavy as is necessary for impelling it with safety on a tolerable level road, merely that it may have power within itself for going up a few occasional hills, or whether it is better to make the machinery lighter, and take the occasional assistance of a pair of post-horses? There can be no objection to the latter expedient, except the

expense of such horses; and as the steam coach can carry goods to profit in place of all the weight of machinery which is saved by making it lighter, I think that the aid of post-horses would be an economy. In forming such an opinion, I follow a maxim which I had always found to hold true; viz. that steam power is certain to be more profitable than horses, if the work is to be kept constantly going on, because then the great advantage of steam power, that it does not tire, becomes fully available; and to perform the same service by horses, a very great number must be kept for change; but for businesses, which require only occasional working, or for working during only as many hours each day as horses can do without changing, steam power loses its great advantage over horses, and in some cases they will do the work cheaper. One great item of the expense of steam power is the first cost of machinery and engineers' wages, both which would be only the same for working twelve hours per day as for one hour and a half, which is the utmost that a stage coach horse can draw at ten miles an hour. A steam coach should work twelve or fourteen hours in every twenty-four hours, to gain the full advantage of the system of steam power over horse labor; the intervening ten or twelve hours will allow ample time for putting every thing in perfect order for the next journey, if the machinery is what it ought to be, and there should be a spare coach for every two which are running, to allow time for more considerable repairs: hence, I reckon that three steam coaches should keep up a double passage of 100 or 120 miles a day continually. Expensive machinery, which is only to be worked occasionally, will not, in some cases, do work so cheap as it can be done by men or by horses without machinery; and that I conceive to be the case with the extra cost, weight, strength and complication which must be given to the machinery of a steam coach, in order to enable it to go safely up steep hills without assistance. I apply these remarks to the present steam coaches, but future improvements may in time produce that species of machinery which will effect the going up hill with less difficulty than the present. It has been supposed that the diameters of the cylinders being larger than is necessary for going on level ground, they could be worked with a diminished strength of steam to go on level ground, and stronger steam when going up hill. To get up ordinary and moderate hills, that is certainly the right plan; but it requires the strength of all the moving parts of the engines to be made sufficient to bear the utmost force that the pistons can exert when impelled by the strong-steam that is ever to be used; also, the large wheels which run upon the road should be made very broad on the edges, and of proportionate strength. The present coaches have been faulty in these respects, and yet the machinery is too heavy. Another way of getting sufficient power to go up hill, is to have the pistons only a suitable size for going along the ordinary road, and to introduce wheel-work, which can be thrown into action when a hill is to be ascended, and which will turn the wheels of the carriage round only once for three turns of the cranks of the engine, and consequently with a triple force. Mr. Hancock has shown me the parts of such machinery which he is now making for a new steam coach, with wheel-work and endless chains, on a plan which I think very likely to answer for ascending moderate hills; but for very steep hills, I think it is desirable to have a help by post-horses. The immediate desideratum is, to construct a steam coach with the power and strength necessary to go quickly and safely along the best lines of road which can be found, without any steep hills upon them, and taking assistance of post-horses where it is necessary. If that is accomplished, and such a

coach is worked continually for two or three years, it would probably lead to the knowledge of the proper kind of machinery to go up steeper hills; but if the adoption of steam coaches is to wait until they are rendered much more perfect, it will be a very long time, because practice is essential to finding out a proper plan.

Do you think there is any danger in going down a hill in a steam carriage? Much less than in a common stage coach; for, by backing the engines, so that their power is brought to an act in opposition to the turning round of the wheels, and with the assistance of drags or brakes, rub on the rims of the wheels, and aid in retarding their motion by friction, steam coaches will safely get down all moderate hills, such as are met with on our best lines of turnpike roads, say between London and Holyhead; and with machinery such as Mr. Hancock is now making, if it is suitably proportioned, I expect a steam coach would not require assistance to get up hill at more than five or six places between London and Holyhead.

Stanmore and Highgate hill you call moderate hills?—Not the old Highgate hill; but the Archway is a very fair road, on which a steam coach should not feel the least difficulty. I do not call those moderate hills which are common on the roads in many parts of Devonshire and Cornwall; it will be a long time before steam coaches will be able to travel there; and the goodness of the roads is to be considered as well as the slope. No steam coach that I have seen, possesses that strength and weight of machinery which, being on the present construction, will enable it to get up even a moderate hill without risk of breaking; for, though it may climb up the hill by accumulating the strength of the steam, the parts have not been made strong enough to resist the strain to which they are then subjected, if they were frequently used; and if the work were made, on the present plan, strong enough to endure the extra strain of getting up a steep hill with safety, there would be too much weight of machinery for travelling on the ordinary road.

Can they ascend a hill so steep as one in eighteen?—That I think is too much for them, without the aid of horses, unless the surface of the road were of the very best quality; but such hills are usually bad roads.

Are they competent to ascend a such hill as St. James's street?—I have not a very particular recollection of the slope of that hill, but I believe it is paved, and I think that it would be about their maximum; for a great deal would depend upon the surface of the road. They would go up all the length of Regent street, which is, I expect, almost as steep as St. James's, but it is a better surface; and I think they should go up any good road not exceeding a rise of one in thirty; and if more inclined, or if the road is bad, they should be allowed one or two horses. I doubt if they could ascend the Pentonville hill in its present shameful state of neglect; but if it is made good, then I think they might.

Have you turned your attention to the subject of apportioning the tolls on steam carriages, so that they may bear their due proportion to the tolls on carriages drawn by horses? No, I have not paid much attention thereto; it is a subject which would require more consideration and more data than I have before me. I am convinced that if a steam coach, complete when travelling, weighs no more on an average than a stage coach with its four horses complete weighs on an average, there is no reason for charging any extra toll for steam coaches, but, on the contrary, I believe it will turn out in the sequelthat they ought to go for less toll, because they will wear the

roads less than the present coaches whenever they are made really efficient; and, in the mean time, until that is accomplished, I think it may be very safely left to the chance of events as to injuring the roads to any extent whatever, by injudicious attempts to work steam coaches of an injurious construction, on the consideration that if any new coach which may be tarted, does injure the road, it will be very soon given up from its own demerits, probably before it has produced any visible effect on the road. Suppose its wheels were to slip so much as to plough out ruts on the road, t would most likely stick fast, or be broken to pieces in the first journey along the road, and such abortive attempts will not be repeated very frequently. It is idle to talk of one or two steam carriages doing much visible injury to a frequented road in a year or two, even if they run constantly, for, suppose that it wears the road four or five times as much as one carriage of the same weight drawn by horses (including those horses in the weight,) it would only be equivalent to four or five additional coaches passing each day, and that on the road from London to Birmingham, for instance, would be quite imperceptible. I am confident that any steam coach which does a road any greater damage than equivalent to carriages drawn by horses, will fail of itself in a short time, and prove an unsuccessful project. I should strongly recommend the new system to be left to its own chance of success or failure, as far as the roads and the safety of passengers are concerned; and I think the same reasoning applies against any regulation for the breadth of the wheels for steam carriages, because they will not perform well if their wheels are so narrow as to cut the road materially. I understand that the old system of regulations and penalties, as to over weights on given breadths of wheels for common carriages, has been done away with on the roads in an extensive district round London, and I think that it is good policy, from the circumstance that the proportion regulates itself by the interest of the owners of carriages, when the fact is understood that carriage wheels, which are too narrow in proportion to the load on them, and to the hardness and goodness of the road, will always draw heavier than wheels of a suitable breadth; and that, though the carriers may not find out the proper breadth at once, they will do so in the end. The old acts for forcing the use of very broad wheels by making tolls operate as penalties and premium, was a most injudicious system of legislation, and did nothing but harm; the carriers soon found out how to evade the intention of the act, by using very broad conical or barrelled whells, rounding on the edges, which conformed to the words of the law, but which acted on the road like narrow wheels. The broad wheels intended to have been encouraged by the old act of Parliament, were expected to act as rollers to make and improve the roads, and were encouraged to carry excessive loads for that object; but if the wheels of the broad wheeled wagons actually used had been really such as the Legislature contemplated, they could not have been continued in use on account of the great increase of draft; but the broad wheels actually used, carried such loads, that they crush the road materials to powder, owing to the conical form of the wheels and the bending of the axletrees; they bore on the road almost wholly at the inner edges of the iron tires, and not across all their breadth, as was intended. The advantage to the carriers in tolls, and in increased loads, induced them to use such broad wheels, when it would have been against their interest to have done so, if they had paid the same tolls for the weight of goods as other carriers, and their operation on the road was more injurious than any other carriages. There is no particular breadth of wheels which

can be prescribed as the best to carry given loads over all sorts of roads, for much depends upon the hardness of the road materials, the size to which the pieces are broken, their general form and disposition to consolidate into a hard bed the resistance the materials offer to wet and frost, and to wearing by the wheels, the breadth of the wheels, and the load upon them, should be adapted to all the combinations of circumstances, and the carrier will soon find, if his wheels are not best adapted to the road, by the draft being greater than it ought to be. As to steam coaches, the wear which will take place on roads, from all that can, by any probability, be expected to be brought into use for some years, will be so small that it cannot be felt for a considerable period, and when it is felt it, will be time to look round and see what is the real effect on the roads of those particular coaches which are in use, and apportion the tolls that they ought to pay.

Is it your opinion that weight for weight, including the weight of horses on one hand, and of engines and an average of the water and fuel on the other, the tolls should be the same on steam carriages as on horse-drawn carriages? I think that if it were so, it would prove a considerable advantage to the roads, because, as I have stated before, I think the roads will be considerably benefitted by the change of impelling by steam instead of by horses. I think it will be a great public benefit when steam coaches come into common use, and hence that it is expedient that a moderate bounty should be offered for the adoption of steam carriages, by giving them all possible advantage they can have without trenching on the interests of individuals; and if they were allowed to run toll free, and duty free, until a certain number were in use, or during a certain time, it would much accelerate their introduction, because it would diminish the loss that must necessarily be incurred by running them before they are perfected in their construction. Small encouragements or discouragements have a considerable effect on new inventions in their infant and imperfect state. The advantage to the public from steam navigation is now generally acknowledged; but when steamboats were in their infancy, an attempt was made by the watermen on the Thames to suppress them, by contending that, according to their charter, and the usage of the city of London, no persons could be allowed to own a vessel plying for passengers on the Thames, nor to work on board of such a vessel, except they were freemen of the city, and belonging to the watermen's chest. This would have effectually prevented any engine men being employed, and, in addition, the watermen engaged all their members to refuse to navigate them. After a long dispute and delay of the steamboats, it was decided that one out of a number of owners being free was sufficient, and that the men employed to manage the engines were not subject to the watermen's regulations of freedom of the river; some watermen were induced, by giving them small shares in lieu of wages, to exercise their right of freedom in favor of the real owners, and to navigate the vessel. It was afterwards attempted to get the measurement and calculation for the registered tonnage of the steam vessels made according to the extreme breadth across the projecting boxes which contain paddle wheels, under the pretext that they occupied that width in the river and in harbors, instead of measuring the breadth of the vessel at the surface of the water. If that could have been enforced, it would have nearly doubled all the rates on steam vessels compared with other vessels; but the subject being brought before Parliament, an act was passed to give them the advantage of deducting as much from the length of the vessel as is occupied by engines and machinery

in calculating the registered tonnage. This was in effect a small bounty upon steam vessels, for they have no claim to such an advantage over sailing vessels, when the weight of masts, sails and rigging, in the latter is not deducted in calculating their tonnage. The effect of that measure has been favorable to the advancement of steam navigation, for though it was but a very trifling bounty, and is now of no consequence, it came as a well-timed aid, at the date when that act passed, because almost all steam vessels were then navigated at a loss, they were so imperfect (like steam coaches at the present day,) that their engines were continually getting out of order, whereby they failed to make their passages, and required expensive reparations, their consumption of fuel was great, and the wear of boiler excessive. On the other hand, few passengers would go by them at first, and some terrible accidents which happened in a few vessels caused them all to be avoided by passengers for a long time. It was only by persisting in keeping them going as well as they could, and thereby gaining experience in their management, that the numerous defects of their construction were remedied. Most of the earliest steamboats had two or three successive editions of engines and machinery before they were rendered so perfect as to become profitable; and, in addition to the expenses of such alterations and improvements in the machinery, they were obliged to make their passages regularly for some time after they were rendered tolerably effective before they acquired sufficient confidence with the public as to their safety and punctuality, to enable them to obtain as many passengers as would pay the expenses of navigating the vessels. For all these reasons, any increase of their expenses was severely felt, at that losing period; many were abandoned, and the difference in the expenses occasioned by the rates to which vessels are liable, being calculated according to the breath across the paddle-wheels, or according to the act passed for measuring them short by all the space taken up by the engines, would have occasioned others which have been brought to bear to have been given up, before they had attained so much perfection as to enable them to earn their expenses. In the same manner the tolls levied upon steam coaches at present are to be regarded, not as payments out of the profits of a gainful trade, but as an increase of loss upon that which is yet, and which must inevitably continue to be for some time, a losing business. The ultimate success to which I look forward is entirely dependent on the circumstance of the first speculators in steam coaches being enabled to go through a sufficient term of inefficient performance, and consequent loss, to acquire experience in the new business; and that experience will, no doubt, lead to expensive alterations and reconstructions of their machinery. There is so much mechanical talent to be had for money, that I have no doubt of the final accomplishment, if the attempts now making are continued long enough; because I am confident that there is (as was the case in steamboats) a real efficacy in the principle of action. The general opinion of engineers was not very favorable to steamboats when they were first brought forward as a novelty; many doubted if they could ever be made to perform well, particularly at sea; and others, who foresaw the possibility of that, doubted whether they would answer in point of expense of fuel, and wear and tear of engines and boilers. If no assistance or encouragement is given to new inventions when they are in the infant state which steam coaches are now in, persons who find that they only lose money when they expected to gain, by being the first to adopt the improvements, are liable to become disheartened, and give up the pursuit too precipitately, whereby their undertaking dies a natural

death; and that is sometimes the case when it might have been established by another two or three weeks' continuance of the efforts: and that continuance might be induced by some small relief, like the reduction which was made by Parliament in the register tonnage of steam vessels, or the taking off of tolls from the earliest steam coaches. If by any means they are enabled to go on till the proper plan of machinery and management is found out, they will afterwards keep their ground, because the profit of working by steam in lieu of horses will be very great. The present steam coaches are mere experiments, and the next editions of each plan of them will, I expect, be losing concerns, and will continue so to be for some time. Under those circumstances, every small increase of their expenses is a real retardation to that practical establishment of the invention which will render it useful to the public; such retardation by small causes is operative to a greater extent than can easily be conceived. Steam coaches will very well bear all tolls and taxes to which other coaches are subject, when they are able to carry passengers regularly and profitably; but they want encouragement now, instead of difficulties being thrown in their way. As to the right of tolls on turnpike roads, it should be recollected that turnpike roads are not property, like canals, but trusts, to be exercised for the benefit of the public; and if it is for the interest of the public that steam coaches should be brought into use, and if that bringing into use will be accelerated by suspending the tolls on them at first, the trustees of roads ought not to object to such an arrangement. The real amount of tolls they will forego, will be an exceedingly small per centage on the income of their tolls; for so long as steam coaches are losing concerns, they cannot be very numerous.

In the course of your examination, have you meant to confine your evidence to steam coaches? Yes, to steam coaches for public conveyance of passengers and parcels in the manner of stage coaches, and travelling at the rate of ten miles an hour on our best lines of turnpike roads, with occasional assistance of one or two post-horses, where necessary, to surmount unusual hills or very bad pieces of new laid road. If it were thought admissible to begin with travelling at a less speed than that, and to carry goods only in the manner of vans, the thing is nearer to accomplishment, because the accommodation and comfort of passengers would then be out of the question; and also the violence to which quick travelling carriages are subjected, requires a greater strength of all the parts than would be necessary to carry the same weight at a slower speed. In other respects, steam power will propel a carriage as cheaply at a quick rate as at a slower rate. That fact is proved on railways, in actual business; and steam coaches will be the same whenever they can be made strong enough to bear quick motion without being overloaded with weight of machinery. That will be one of their great advantages over horse labor, which becomes more and more expensive as the speed is increased. There is every reason to expect, that, in the end, the rate of travelling by steam will be much quicker than the utmost speed of travelling by horses; in short, that safety to travellers will become the limit to speed, as is now the case on railways.

What is your opinion as to impelling wagons by steam? I have never considered that at all in detail, and am not prepared to give evidence upon the subject. The price of carrying passengers or goods at a quick speed, as is done by stage coaches or vans, will always be so much higher than the prices of carrying an equal weight at a slow speed, as is done by wagons, that I see no inducement to attempt steam wagons, which I think would

present almost all the same difficulties as steam vans. According to theory, the cost of carriage by steam will (as I have stated, be proportionate to weight and distance, without regard to speed of motion; for instance, to convey a coach loaded with two tons for a distance of ten miles only, the same fuel will be consumed, and the same wear of machinery will be occasioned, whether that distance is run in one hour or in four hours. The wages of engineers, conductor and guard will be only one-fourth with the quick speed, and the first outlay in machinery would be only one-fourth, because four times as many engines must be on the road, with their attendants, at the same time, to do the work at a slow speed, as at a quick speed; but the money earned by the carrier at the slow speed, will be only a small part of what would be earned at the quick speed.

Taking into consideration the comparative expense of horse carriages and steam carriages, do you suppose that steam carriages will be able to run for half the charges of horse carriages? My own idea is, that steam coaches will, very soon after their first establishment, be run for one-third of the cost of the present stage coaches; but to become a business at all it must necessarily be a business which will offer strong inducements to persons to embark in it; and to do that, the rate of profit must be very much greater than that which is commonly expected to be realized by the proprietors of stage coaches. Their present trade affords a less profit on the capital and trouble of management probably than any other sort of business which is carried on with spirit in this country. The great reason of that is, the constant loss by destruction of horses, the fluctuations of the price and quality of horse-keep, and the impossibility of reducing stage coach establishments in times when travelling business is flat; because the horses must be kept and men to attend them at all events, and the loss of running a coach half employed is not so great as suspending it, and keeping the horses idle on short allowance, till better times come round. The profit of stage coaches which load well is very high, particularly in the fine travelling season, and that occasional profit creates an excitement which induces the injudicious setting up of more coaches than are wanted for an average of all seasons; and for the reasons above stated, their expenses when once set going, cannot be reduced to meet bad times. The adoption of steam coaches will set the trade free from its great commercial difficulty, because they can be laid up and kept idle without considerable loss, and brought out again when wanted without any new outlay; also fuel does not fluctuate either in price or quality to any considerable extent like horse corn. In short, the capital embarked in a steam coach trade will not be so rapidly wasted as at present in horses. Owing to the great number of horses which must be first bought and then kept to do the same work as one steam coach, the first outlay in stock will be very small in steam coaches, compared with horses, the same of stables, hostlers and harness. The daily expenses of fuel and attendants will be very much less than that of horse keep and attendance; the wear and tear of the coaches, and all that is coachmaker's work, will be only the same as at present, but the wear and tear of engines and machinery, though a very expensive item on each engine, will be nothing to compare with the present repairs, loss and decay of horses, because the number of engines is so small. Stage coach horses require to be all renewed every three years, notwithstanding a heavy annual expense for what may be called repairs of horses: viz. harness, shoeing and farriery. Engines with an equally heavy annual expense of repairs to that of horses, will, when per-

fected, be kept up thereby in such a state as to last for many years without renewal. The metal parts of machinery only wear at particular places, which are capable of being repaired or renewed, so that they become as good as new; but a horse, when worn to disease at any part, feet, eyes or lungs, becomes incapable of stage coach work forever afterwards.

Do you apply the principle you have stated respecting the probable wear of the roads by steam power being less than by horses, to heavy wagons? Yes; my proposition that the wear of the roads will always be at the expense of the carrier, applies to all carriages whatever, but more particularly to those impelled by steam than to those drawn by horses, because carriages drawn by horses may be so mismanaged, as to do very great injury to the roads, and yet may make good progress in travelling. For instance, a wagon having very narrow wheels, carrying a heavy over-load, having a sufficient team of strong heavy horses, may be drawn along although it breaks the road up to any extent, and that as much by the feet of the horses as by the narrow wheels; but, if it were attempted to impel the same wagon by steam power acting by the adhesion of the wheels to the road, they would slip round, and it would not get along the road. I am confident that carriages to be impelled by steam machinery turning the wheels, cannot be made to answer any good purpose, either for conveyance of travellers or goods, so long as they materially injure the roads, because if the wheels slip materially on the road, or if they cut sensible ruts in the road, they will not advance the carriage efficiently. On the other hand, horses may be made to draw a carriage which will injure the road. I think that principle must apply to steam wagons as well as to steam coaches.

Then heavier the loads to be drawn, the more important it is to apply steam instead of horses, if the roads will be benefitted by that substitution? I think so, as far as the roads are concerned, but I doubt if steam wagons will offer any comparison of the profit to be derived from steam coaches. To get along the road, steam wagons will require very broad wheels, and there is no danger of doing injury to the road by them, for they will not get along if the wheels are too narrow, but narrow-wheeled wagons drawn by horses may do an injury to any extent, for extra horses may be put on, and they will injure the road with their feet at the same time that they draw a carriage after them, which also injures the road. It will be a loss to the carrier to do so, but there is nothing in the nature of the operation to prevent it being done, as there would be in the case of steam wagons.

Of course, a steam carriage going slower than ten miles an hour will be more expensive to travel, on account of the greater expenditure of fuel? No; the consumption of fuel, according to time, would be as much less as the motion would be slower; so that the consumption of fuel, according to distance, would be the same, whether for a quick speed or for a slow speed; but when profit is considered, every thing is in favor of quick speed; because all goods carried slow must be carried cheap; and quick conveyance will bear the highest price of carriage, on account of the expense of going quick by horses. For instance, a ton of goods may be carried a mile by steam power with a certain consumption of fuel, but it should take no more fuel to carry it a mile, at the rate of two and half miles an hour, than at ten miles an hour. There is some qualification to be made in that statement according to the state of the roads; it will be true if they are hard and good, but if they are heavy, the expense of fuel will be a little more for the quick speed than for the slower speed; and it is also to be understood, that the engines must be suitably proportioned for attaining quick speed, because engines,

which are only adapted for slow motion, do not work to so great an advantage when they are urged to work quick as when they are worked at or below the speed which the proportions of their parts are adapted to move with; nevertheless, that extra expense of going quick by steam power will be but small, and nothing like the increased cost of travelling quick with horses; for horses have only a limited speed at which they can travel, if they have no load to carry or drag after them, the whole of their muscular strength being then required to advance the weight of their own bodies. The speed with which stage coaches now travel, approaches so near to the speed with which the horse could travel without any load, that their force of draught becomes very small. In all cases, horses lose force of draught in a much greater proportion than they gain speed, and hence the work they do becomes more expensive as they go quicker. The quickest stage coaches travelling is now at the rate of eleven miles an hour, and that appears to be very near to the utmost limits which nature has prescribed for animal exertion; for those horses require renewal of the whole stock every two or three years. This is a comparison of steam power and horse labor, during the time that each is actually in operation; but the real difference between the performance of a steam engine and that of a set of horses will be found to be very great, when it is considered, that, by having one spare steam coach for every two or three which are on the road, those coaches can travel continually all the year round, during fourteen or fifteen hours in every twenty-four hours, without any intermission, except stopping for one or two minutes to take in water at every stage of about seven or eight miles; and thus each steam coach can travel 140 or 150 miles a day; whereas a set of four stage coach horses can only work during seven hours and a half out of every twenty-four hours, or each horse can run fifteen miles a day, and that exertion wears them out very soon. A cart-horse, travelling at the rate of two miles and a half an hour can work during eight hours out of every twenty-four hours, or he can travel 20 miles in a day. Suppose that in both cases, of horses going ten miles an hour or only two miles and a half an hour, the force of traction was the same during the time that they were actually drawing; even on that supposition, there would be the difference between twenty miles a day and fifteen miles a day in favor of slow travelling; but in considering the work performed, the great loss in the force of draught by quick travelling must be taken into account; and it will be found that a cart-horse walking at two miles and a half an hour, could draw with a force of traction 100lbs. on an average, but that a stage coach horse, running at ten miles an hour, cannot exert more than 28lbs. force of traction at an average. The above proportion of distance travelled, and force of traction exerted in each case being combined into one product, the portion will stand thus: 20 miles a day $\times$ 100lbs. draught$=$20,000, to represent the work done by a horse travelling at the rate of two miles and a half an hour, and 15 miles a day $\times$ 28lbs. draught$=$420 to represent the work done by a horse travelling at the rate of ten miles an hour, which is 4$\frac{3}{4}$ to 1 in favor of a slow speed; when with steam power there would be only a very slight difference of performance at the quick or the slow speed.

Respecting the injury done to the roads by heavy carriages, whether they are drawn by horses or impelled by steam power, you consider that weight for weight (including horses and engines as part of the weight) the one will not do more injury to the road than the other? In my opinion, the steam carriages will do the least injury of the two. The horses, by tread-

ing with their feet, excavate and scrape out depressions in the surface of the road, that is particularly the case before the road materials are consolidated into a solid mass; and the evil of depressions or holes in the road is not the merely injury done by the feet of the horses to those particular parts of the road in which the depressions are made, but the wheels of other carriages which pass over such depressions, drop heavily with force in to them, so as to make the depressions continually deeper and larger, and to loosen the surrounding stones. In this manner the horses after injuring the road themselves, prepare the way for further injury to the road by the wheels of carriages. For to have the full benefit of the rolling action of the wheels in consolidating the road materials, the latter must be laid smooth and level before the wheels come upon them; but if the materials are previously thrown up into little hills and holes, the wheels will do mischief instead of good.

Suppose the engine and machinery in a steam carriage to weigh two tons, and to be able to advance an additional load, equal to their own weight along a good road, at an average speed of ten miles an hour, do you think that any additional toll should be imposed upon steam carriages beyond that paid by four horse stage coaches, or vans; assuming the four horses to weigh two tons, and to draw a load of two tons, at the rate of ten miles an hour? In such a case, I can see no reason whatever for any increase of toll; but the diminished wear of the roads, which I anticipate from the use of steam in lieu of horses, will be a reason for a reduction of tolls whenever such a diminution of wear is realized.

Would horses drawing 80 cwt. upon a road, with a slow walking pace, in your opinion, do more injury to the road than an engine doing the same work? I have had no experience of drawing heavy weights by steam to enable me to form an opinion respecting the effect that the broad wheels, which must then be used, would have on the road, and what advancing power they would have before they began to slip on the road, without advancing the carriage forwards; nor what would be the weight of engines which could advance 80 cwt. at a slow speed. I feel some doubt of the practicability of making steam engines advance so many times their own weight, as I expect it would be, with effect, and I feel confident that, in the present state of the art, there would be no profit in doing it; but if it were accomplished, I believe that the broad wheels of the steam wagon would do no injury to the road, whereas, in heavy wagons drawn slowly by horses, the horses do far much more injury by digging and scraping with their feet than is done by the horse in coaches and vans travelling quickly; because the wagon horses having a heavy pull to take must choose places in the road where they can place their feet in depressions, in order to get hold; hence, on a good smooth road they slip and scrape up the surface.

Veneris, 12° *die Augusti*, 1831.

Mr. Richard Trevithick, called in, and examined.

Have you been long conversant with steam engines? Twenty-six years ago I invented a high pressure steam engine and a locomotive engine, and since that time Boulton and Watt's engines have been thrown aside in Cornwall, and the high pressure steam engines, with the improvements upon the

boilers I have made, have been throwing Boulton and Watts's engines constantly out of use, there is not one of those now in use in the mines. The average of the duty of Boulton and Watts's engines, about twenty years ago, was taken by Mr. Gilbert, which gave, perhaps, about seventeen millions of pounds, lifted a foot high with a bushel of coals; and sometime after that Mr. Gilbert made a report in the transactions of the Royal Society, that he had found one of my high pressure engines in Cornwall was doing seventy-five millions; and, in the same report, he stated that they were doing nearly as seven to twenty-eight, or four to one, and as ten to one on the atmospheric engines.

Have you lately paid attention to steam carriages on common roads? I have noticed the steam carriages very much; I have been abroad for a good many years, and had nothing to do with them until lately, but I have it in contemplation to do a great deal on common roads; railroads are useful for speed, and for the sake of safety, but not otherwise: every purpose would be answered by steam on common roads.

Is your machine applicable to steam carriages? It is chiefly for that purpose, it works without water; now the Manchester carriages use four tuns a day, two tuns that they take in when they start, and two they take in mid-way of their journey; there is that weight to carry, and the loss of time.

You conceive steam carriages to be applicable to common purposes? Yes, to every purpose a horse can effect.

Have you any plan particularly applicable to that purpose? Yes, I have taken out a patent for that purpose. This, the plan which I produce, *(producing the same,)* will show the principle. I built a twenty horse engine in Cornwall, in order to try this: this I produce is for a ship engine. [*Mr. Trevithick explained to the committee the different parts of the machine on the plan.*] The bursting of boilers has been occasioned by the boilers being left under gauge, neglected to be charged with water, and, I believe, by their getting foul and incrusting with salt from using salt water; the low pressure engines have burst as well as the high pressure; if the tubes of the boilers are heated-red hot, and the engine is standing at the time water is still in, the boiler is quiet; but on the engine setting to work, a discharge of steam from the boiler to the cylinder causes a great ebullition in the boiler, and the water splashing over the hot sides make a superabundant generation of steam. The space that would be filled instantaneously from the hot tubes being suddenly cooled, the space occupied by that superabundance would fill three hundred times the space usually allowed for steam, and a safety valve of five times the size would give no relief, or not in time; a proof that a high pressure steam engine boiler has not been broken generally by the pressure of the high steam, but from being heated, is because the portable gasholders are about ten inches diameter, and the sixteenth of an inch thick, and they are charged with 30 atmospheres, or 450 lbs. each without accident; an accident never happens to them, and the pressure is not so great as on half of the strength of iron; the boilers of steam engines in Cornwall have burst that have not been loaded to an eighth part of that pressure for the same substance and size of boilers. Therefore, that is a proof that they must have been broken by the heating of the boiler, and suddenly cooling it by a sudden expansion. The gas holders have never been heated, and have never been injured. I have known instances whereby turning cold water into a red-hot boiler they have exploded. An engine I had the care of was injured by neglect of one of the enginemen in that way. The boilers to the high pressure steam engines on my construction are cylinders,

one in the other, the inner cylinder containing fire, and the outer cylinder surrounds the water, and leaves a space of about a foot between the two tubes for water. Where they have been neglected the fire tube has been made red-hot, and the splashing of water over the hot tube from the ebullition occasioned by the escape of steam, has burst the boiler by the water flowing over the red hot sides, and generating steam faster than it can be discharged.

By neglected you mean that the tubes were not completely covered with water? They are not covered with water. With my inferential engine, that never can be the case.

Have the goodness to state to the committee your opinion with respect to the wear of the road by steam carriages? I think that the roads will not be injured so much by steam carriages in future as they have been, because there will be no need to chain the wheels; by putting the valve to the stop, the steam going off that has never yet been applied, there is no need to chain the wheel. That is very easily done; if the steam is prevented escaping, the piston must stand still, and it can be let down as gently as possible; they may either stop instantly or go as easily as they please; the throttle barrel will answer the purpose to throttle between the cylinder and the discharge pipe; that would be saving of the roads.

Have you made any observation on the injury done to the road by a carriage propelled not in the usual manner, but by a motion communicated to its wheels? I think the roads would be less injured by steam carriages than by horses, because the wheels will have very little more to carry now than they have with horses, and there are no horses' feet to injure the road: therefore that part of it is saved; the engines now will be so very light that it will be scarcely felt. The power to draw the carriage will be very little more than the weight of harness on the horses.

Would you be inclined, for the advantage of the road, to give greater width to wheels if you give greater velocity? I would rather give greater width; I do not think the road is injured so much; there is less friction. If a two inch wheel goes two inches deep, and a four inch wheel goes only one inch deep, there is two to one difference in the friction, for the ascent in getting up out of a two inch rut requires a great deal more friction. The wider the wheels, in my opinion, though the greater extent the less friction; they use wide wheels to go over soft ground on farms to prevent their sinking; there is a great friction, for it is always going down hill, and the friction is pulling it up hill. There is a power thrown away, but that would not have been the case with a wider wheel.

Do you think for a greater weight with a great velocity of carriage, you could put wheels so wide that. instead of doing injury, they should do good to the road? Yes; I think if the wheels had been as wide as they ought to have been to take the advantage of ease, they would rather have done a service to the road than an injury, that is, to settle down the road; but the greatest folly I have ever seen is the wide wagon wheels which go free of turnpike duty: one part is nine feet round and the other part not above seven and a half or eight feet, one part is going faster than the other, and the one part must rub; had the wheel been upright, and it was turned off, the point only would meet, but it would not be rubbing.

There is a particular width of wheel in which no injury will be done to the road, but rather good? It will be rather good after the road has been mended to settle it down; there will be wear in it as at other times; but in

certain states of the roads, to settle them down, they will doing good, but at no state of the road could it do good with narrow wheels.

What would be the effect when the road was once settled? You see very often roads which have been gravelled; in dry weather the dust blows away; they can never settle again, but if the broad wheels passed over to crush it over with the dust, it would settle down much firmer; but the narrow wheels slide so easy through, that they sink down, and shove them on each side.

Is there any state of the road in which you think a wide wheel would do injury to the road? No; there is no state of the road in which wide wheels will do an injury; if there was to be a wheel of an inch in diameter instead of six inches, it would be like a stamping wheel cutting the road constantly, but the width of the wheel takes off that: the tenacity of stone is equal to the weight.

Does not the whole of this refer to wheels that are cylindrical and the axles horizontal? Yes, they ought to be straight; that is, the very wheel which I want for a steam carriage with straight axles.

Is not the road injured in two ways by the wear of it, and by the separation of the materials? The separation of the materials is not so likely to takes place with wide wheels as with narrow.

That is the reason why narrow wheels injure the roads more than wide wheels? Yes; and there is a much greater weight upon one pebble than is thrown on two or three; double the weight is thrown on one pebble than would otherwise be; then that pebble is crushed; for the stone does not bear strongly enough together to resist it.

For this reason, the operation of horses' shoes must be much more injurious than that of broad wheels? Yes; they are more likely to break the hard stones than a dead weight. I think the horses' feet much more likely.

There are certain states of the roads in which the widths of the wheel would occasion your losing power, are there not? No, I think not, I have heard that mentioned, but I think it is not so.

Is there any slipping or sliding in the wheel of the steam carriage? When the trial for the premium given on the Manchester railway was decided, the engines ran for a certain time, and the strokes were counted, and the distance was measured, and there were remarks made upon that day's peformance: they found, by measuring the periphery of the wheel, the number of the strokes made, and the distance run, that there was not the least variation whatever: they could find no difference.

Was not that on a railroad? Yes.

The cylindrical wheel, with the horizontal axle, is the best for the road? Yes.

Is there not much less likelihood to slip on a common road, than on an iron railroad? Yes.

Suppose there are sharp ascents upon a common road, how would that apply? There is no ascent that any common carriages go over, where the steam carriage will not go down the hill with one wheel chained; no road in the neighborhood of London that they would not run down with one wheel chained; that is, only one quarter part of the weight of the carriage, if the wheel is chained. If you are drawing up hill with two or four wheels driven by an engine, by their all turning round, they are as likely to go up hill. One wheel ought to put it up hill. It will go up a hill of double that ascent without slipping.

Will the increasing breadth of the wheel render slipping in ascending a hill more or less likely to take place? I rather think that will increase the friction, because that does not tend to make a rut. In making a rut, there is a very great difficulty in the wheel getting out of that rut, for there is no footing; but where it does not sink, that is not the case.

Supposing the width of the wheel to be the same on a carriage and a steam engine, and the weight of the carriage the same, do you consider that a wheel perfectly cylindrical, with a horizontal axle, preferable to a wheel dished like that of a common stage coach, with a common axle? You cannot have a dished wheel to a great width, without its dragging as I have described, unless you alter the system. If you keep the present dish, you must have a narrow wheel, or it is rubbing; but if it is a straight axle, it ought to be as wide as that where there is no more friction, and then the wide wheel will not do half the mischief that the coach-wheel does. The present stage coach-wheel will do a great deal more mischief, working as it does, than if it had been perpendicular.

Are you to be understood that, in no state of the road, a wide wheel such as you have described would do injury to the road? A wide wheel will do a partial injury, but not one quarter of that which it would do if it were narrow.

What sort of injury will it do? It will tend to crush the pebbles and wear them, but that will be very trifling indeed; if you have a hundred weight upon a wheel of an inch wide, and a hundred weight upon a wheel of two inches wide, that one of an inch wide will break ten times as many pebbles as the other; every inch it goes will break stones; a wide wheel does away the injury.

You are aware that in the carriages that run at present on the common roads, the wheels do not run in the same track—in the event of having wheels with the tires four inches wide, do you think it would be better that the tire of the hind wheels should run in the same track or a different track? For the carriage making one turn only, it is easier for the wheels to go on the same track; but if you wish to take the average of the duty, they never ought to go in one track.

You think, in the steam carriages, that the tire of the hind wheels should go in different tracks? Yes; the one produces a burr, and the other smoothes it down.

Will the carriage run so easy? No; it would for one turn; but, in the course of time, going every day backwards and forwards, the work will be done easier.

You think the tire may be extended to almost any width: what is the width which you think a steam engine travelling rapidly ought to have? It depends upon the weight they have to carry; but if you draw a conclusion from the coaches carrying four tons on two inch wheels, you might, with a great deal of convenience to the engine, make them six; but a six inch wheel would not break one-tenth part of the stones which a two inch would.

You see no objection to a steam carriage, intended to travel fast, with passengers, which may weigh as much as a coach and four with its horses, having a six inch tire? No; I know it is condemned by people in general; but I have never heard, nor have I seen, any reasons for its being condemned.

The wheels being wide and being cylindrical, with their axle horizontal,

supposing you were to double the diameter, or to increase the diameter considerably of a wheel six inches wide, would it go more easily for the road? It would go easier for the machine; but then there must be a wheel of double the width, and that would be loading the machine in going up hill with an unnecessary weight; but that would ease the road; it will have a longer bearing on the ground; there would not be so quick a circle.

With respect to the road, there would be a considerable advantage? Yes, for it is a larger arch.

With respect to the engine, would there be any other disadvantage but the additional weight? No; I do not know any material objection except that, and that would throw the engine very high; it would be top heavy. I do not think it would be convenient to make wheels above six feet.

Can you state the weight of your engine as compared with the weight of the present engine? I will furnish an answer to that question.

Do you conceive that your engine, of which you have produced a plan, is as applicable to carriages on roads as to the propelling engines at sea? Yes, that is one object I have in view, and for agricultural purposes, for ploughing, and every other purpose.

Have you ever calculated what the weight of a carriage would be with one of your engines? Yes; I am looking to see the necessity of the doing away with the supply of water that I have done away with; but, in dispensing with the water, I shall save three-quarters of the fuel; every time we double the force of steam we save seventy-five per cent. upon it. This engine, I conceive, will not take one quarter part of the fuel; one charge of water will do for a month. I have just taken out a patent for my engine.

Do you condense with a sufficient rapidity to take from the piston the pressure of the returning steam? Yes; there was an engine which had been working with high steam and one of my boilers, and the cylinder was enclosed with brick work to keep off the external air: while I was abroad they took down the brick work, and set it at a distance from the cylinder of four or five inches, and turned the draught from the fire round the cylinder to keep it off, and from that made more than sixty per cent. difference in the fuel; if the engine was doing forty millions to a bushel of coals before, it then did sixty-three millions, and they burnt five bushels of coals to keep the cylinder hot. If they had put that under the boiler, it would have done forty millions as before; but in putting in five bushels round the boiler, it did three hundred and fifty-six millions; then the difficulty was to know how it would make that difference. I could not at first make it out; however it turned out afterwards how it was, and it was the steam; when coming in upon the piston, the cold sides of the cylinder took out a part of the heat; these are single engines; the steam is returned under the piston upon the engine going that stroke again. The cold sides of the cylinder caused a dew by the steam; the steam was expanded to full four times the space; by the time it had gone a quarter part it was shut; then it was expanded; it was entirely cooled by itself; but when it came to touch the cold sides of the cylinder, it hung about them like a dew. The moment there was a communication to the condenser, that instant it expanded, and it threw itself into a second ; the next stroke threw that heat again into the side of the cylinder; the weight of the cylinder was about six tons; if it had taken out one degree each time, that would have taken out more than the engine burnt. There is a clear proof how quick cold will condense.

Are there not steam engines in which the cylinder is within the boiler? Yes; those are commonly used now in the high pressure steam engines.

Have you ever considered what toll should be charged upon steam carriages, assuming that a steam carriage of 40 cwt. is equal to four horses, and does no more damage than four horses would do upon a road? I should judge that there would be no need to fix them heavier than just to pay for repairing the road, whatever it may be; people are not to get their maintenance out of roads; and if the steam carriages do not injure the roads half as much as a common carriage, they should not pay half so much.

You do not suppose that a steam carriage weighing four tons would do more injury than a horse carriage? A steam carriage with the same weight would do nothing like the same injury as a horse coach, for they have narrow wheels and these have not; and there are no horses' feet.

Your opinion is, that there should not be a higher toll charged upon those steam carriages than upon a coach drawn by four horses? If the toll is charged according to the injury done to the road, it would be not more than half.

Do you conceive there would be any difficulty in applying steam carriages to the present roads with the present ascents? Under the present circumstances there is a difficulty. It is a question whether it shall go over the road, for the weight is too great; but if the weight is done away, and three to one in power added, it will be possible to do it, and I have no doubt it will be effected on my principle.

You think that the steam engines already prepared would go on the common roads? They are between sinking and swimming at present, and I think they will swim: I think that the improvement is effected, and that they will do.

Would it not lighten the weight of engines if you had fixed stationary engines to pump gas, fifty atmospheres for instance; and shift the vessel containing it at each stage? We do not want air or gas.

Something that has a power to drive? A vessel that weighed that would be so heavy, it would not carry its own weight; the vessel it was compressed into would be of considerable weight; a cubic inch of water will fill a cubic foot.

In the application of your power to a steam carriage, do you suppose there would be less danger of bursting than at present exists? Yes; this cannot burst; that is prevented.

Have the goodness to state your reason? There are five separate cylinders, the one encircled in the other; and if the boiler, or the inner circle burst, there are four other circles that might take the pressure, one after the other, before it can externally explode, which outer circles are never heated; and the boiler can never be heated or low, because the steam that is made use of by the engines is returned every stroke into the boiler, and provided an engine is tight, it may work forever without a fresh supply of water.

What height would the shaft be, as applied to your steam carriage? It does not require to be higher than a common steam carriage.

Have the steam carriages that now ply on the roads a shaft? No; they get the fuel through a fire door, but it will answer best to fill through you get considerable advantage. In the first place you have a less boiler; by having a less boiler it is lighter; it is much stronger by getting a greater

pressure; there is 75 per cent on the fuel. If you take the average of the advantages, it will save daily nearly ten to one on travelling engines.

That will render it necessary to have a chimney in a steam carriage? A chimney is not necessary for the sake of draught if there is a forced draught. The engine of which I have produced a drawing, is made for a ship, where we are not bound to height, but five or six feet would be quite sufficient.

Do you apprehend that, in your engine, there would be any noise from friction, so as to alarm horses? No more than in any other engines; there is no more noise; whether the steam is generated in the same way or how it is conducted, makes no difference.

With what would you work? With coke; that would be the most convenient.

Do you think the road would suffer less damage from the carriage itself containing the engine conveying the passengers, or conducting another carriage intended to convey passengers? I think it better to have separate carriages for the roads, as well because there is less weight upon the wheels; The weight would be more equally divided on the four wheels; but there will be six wheels in a general way I think. The two fore wheels will bear very little weight.

Might not a single truck wheel do for that? It would not be steady.

Mercurii, 17° *die Augusti*, 1831.

Mr. *Richard Trevithick*, again called in, and examined.

Are there any additional observations you wish to make to the committee?—There are. I was asked what I had performed, and what was my opinion as to whether steam power could be made useful on common roads in general, and the difference in effect between broad and narrow wheels on such roads, respecting their breaking up or settling down the surface, and what farther advantages I might expect from my late improved steam engine? In answer, I beg to say, in 1804 I invented and introduced the high-pressure steam and locomotive engines, and, also, in 1813, invented the iron tanks and buoys for his Majesty's navy. In 1814, I was engaged by the Spanish Government to construct in England nine high-pressure steam engines, and a mint, with pump-work, and every thing complete for draining the great mines of Paseo, in Peru: they weighed 500 tons, in 20,000 pieces, the boilers each of six tons weight, all in single plates, and the cylinders each in six pieces, all carried up the mountains on mules' backs, and put together on the spot, by which the mines were effectually drained, the ores wound up, stamped, smelted and coined; they remained in full work until the Spanish army retreated through the mines before the patriots, and, on their retreat broke the engines, and threw them into the engine pits. For a report of my progress in Peru, see the first number of the Geological transactions of Cornwall, copied from the Lima Gazettes. In reply to the questions put to me by the committee of the House of Commons, respecting the probable process of steam power for locomotive purposes, I beg to say, on railroads, they have been proved to be useful to a certain extent, but are still defective, on account of their great weight of machinery and water, and the difficulty of getting water at all times, also a want of permanent safety against explosion; but, from a

a late improvement of mine, these obstacles are now removed, and when these late improvements are combined with my former locomotive engines, they can be constructed so light as to travel at almost any speed, and thousands of miles, without a supply of water, and the risk of exploding is reduced to an impossibility, with a saving of considerably above fifty per cent. in fuel; all those improvements will appear in my statement hereafter. Travelling on common turnpike roads would be by far the greatest national advantage, but which, on the present plan, never can be accomplished, because the difficulties of getting a supply of water, and the inequalities of the surface of the roads, will always, under these circumstances, prevent the limited power to ascend the hills; and this objection is irremovable, because, as the power at present increases, the weight increases in nearly the same ratio. At the present moment, we have a proof of this, from the engines travelling on common level roads being as nearly as possible in equilibrium, their power just capable running their own weight at a fair speed on a level surface; and they now only wait an increase of their power, independent of weight, to accomplish their general adaption to every purpose, both on the road and also to agriculture; and as the expense of fuel bears so small a proportion to horse labor, the removal of the present objections would accommodate their general use to unlimited advantages that the public are anxiously in search of. As the axles of steam carriages require to be straight, and the wheels perpendicular, there remains no objection to employing any width of wheel that the road inspectors require, which, to a certain extent, will reduce the resistance, instead of increasing it. It is my opinion, that all wheels now in use on common roads are much too narrow; but this ought to be accommodated to the materials that the road is formed with: for instance, narrow wheels on an iron road do not yield to the pressure of the weight, but keep themselves perfectly horizontal, and do not pulverize; but every Macadamized road, more or less, is subject to this inconvenience, and the narrower the wheels, the greater mischief is done to the road, and more resistance is given to the horses. The usual notion, that wheels grind the road, is wrong; if any difference, it is the roads grind the wheels, the road-material being generally the harder of the two; but the roads are injured by the wheels crushing the stone, by a narrow surface bearing on small points, or on single stones, the tenacity of which will not support the weight under narrow wheels: under wide ones, they would sustain no injury, because the wide wheel reduces its weight on each inch of surface in contact with the road, as the number of surface inches is increased by its additional width, and settles down the road firmly, and gives each stone a side support also. Therefore, by double the bearing on the road, half the weight is taken off from every bearing surface inch; and that, in addition to the side support, by being bedded firmly, a wide wheel will, I have no doubt, save four out of five, if not nine out of ten stones that are crushed at present, and reduce the road expenses in the same proportion; but while the fancy of having carriage-wheels out of upright with crooked axles is continued, wide wheels would be a serious objection. The inside and outside of the wheel being of different diameters, and going different speeds, must cause an increase of load to the horses, because their rubbing on the road and tendency to twist move the stones out of their bed in the road, and, instead of bedding them firmly, has the contrary effect. Another great evil arises from the use of narrow wheels: they sink lower into the road, and the road being in part elastic, whatever that may be, is a resistance added to the horses according to its perpendicular rise and

fall. The passing over sand or snow gives a proof of this on a larger scale, and wide surfaces will bed snow, and form a firm road, while narrow surfaces would defeat the effect. Another proof of wide surfaces bedding firmly is seen in Cornwall, where the mills for stamping the ores in the mines have steam engines in constant work, lifting twelve inches high iron stampers of three or four hundred weight, of about seventy inches of bearing: at the bottom surface these form their own bed, which is about a foot thick of Macadamized stones, and are an everlasting foundation, though the stamps pulverize at the surface as fine as sand. It would be advisable for the fore and hind wheels of carriages to run about half the track out of a line from each other, because the bank that is formed by the fore wheel would be rebedded by the hind one, and the leveller the road is kept, the less the jolts, and of course the shoaler will be the ruts, while the surface of the road remains sound, and even the wear is scarcely any thing, and the crushing cannot take place but in a very small degree; because the small gravel, binding uniformly with the larger stones, supported on every side, brings the whole surface into uniform contact with the wheel, in which state but very little injury can be done; but when uneven or broken, the loose stones roll about without a support, and kept so by narrow wheels, they independently receive the whole weight of the wheel, and, instead of being bedded down, are crushed to powder. The unnecessary resistance given to carriages and wear of roads by narrow wheels, far exceeds all conception. As a proof that locomotive wheels will not injure the roads by slipping round, I give you the copy of a report printed on the performance of the locomotive engines on the Manchester road for the premium. The following calculation, founed on the reported result, was made by Mr. Vignoles and Mr. Price, of Neath Abbey. The maximum number of strokes was 142 per minute, while 440 yards were traversed in 43 seconds; diameters of wheels 50.1 inches, circumference 157.4 inches; 157.4+142 inches, equal to 621 yards, being the velocity per minute of the circumference of the wheel, or 21 miles and 300 yards per hour: then as 60 seconds is to 621 yards, so is 43 seconds to 445 yards. Thus, the calculated distance of the run, considering the wheel as a perambulator, agrees within five yards with the space actually passed over, and this difference might arise from the most trifling inaccuracy, of noting the time, a quarter of a second at each end being sufficient to produce this discrepancy, so that it might fairly be concluded there was no slipping of the wheels at a velocity of nearly 22 miles an hour with a load. If wheels will not slip round on iron roads, there can be no doubt but that they will be firm on common roads. A steam carriage never needs the wheel chained, or to be still in going down hill, because, if a throttle cock is put between the discharge pipe and the piston, it cannot go down hill any faster than the steam is permitted to make its escape from before the piston, and, if required, would stand still intstantly. Below is stated the commencement of both my high pressure and locomotive steam engines, with the advantages derived from them. Since 1804, at which time I invented and erected this high pressure engine, up to the present time, little improvement has been made in addition to my own. The first locomotive engine ever seen was one that I set to work in 1804, on a railroad at Merthyr Tydvil, in Wales, which performed its work to admiration, a correct copy of which is now in general use on the railroad. The advantages gained by this improvement was a detached engine, independent of all fixtures, working with five times the power of Boulton and Watt's engine, without con-

densing water, and the fire enclosed in the boiler surrounded with water, and a forced draught created by the steam for the purpose of working on the roads without a high chimney; and from this was copied all the boilers for navigation engines, which, without it, could not have been available; this being independent of brick work, light, safe from fire, and occupying little room. In March, 1830, Davies Gilbert, esquire, then president of the Royal Society, wrote a treatise on the improvement made in the efficiency of the largest steam engines in the world, then working in Cornwall, in which he states, that, in 1798, he made trial of Boulton and Watt's engines in that county, and found the average duty performed in the mines was 17,621,000 lbs. lifted one foot high with one bushel of coals; and, in 1830, when he published his treaise on the improvement of the steam engines in the Cornish mines, he says, that the improvement was so great that a duty of 75,628,000 lbs. lifted one foot high, with the same quantity of coals, was then performing in the mines; that when compared with the duty done in 1795, the improvement exceeded Boulton and Watt's engines, as 3.865 to 1, or 27 to 7 nearly; and exceeded the standard of the old atmospheric engines, that were at work in 1778, as 10.75 to 1, (at present some of the best engines have performed a duty of 90 millions with a bushel of coals,) and the result of this great improvement has been, that not one engine on Boulton and Watt's plan remains at work in Cornwall; and it is acknowledged by all the Cornish miners that this improvement solely has been the salvation of their deep and extensive mines, without which the mines could not have continued to work; but, from this increase of power and speed, a duty and saving both in fuel and size of four to one, which has caused the saving of coals in the Cornish mines alone to exceed one million sterling, and a constant saving of above one hundred thousand pounds per year. The saving of fuel in theory, by working with high steam, is 75 per cent. every time that the elasticity of the steam is doubled, because double the quantity of coals doubles the pressure, aud increases the bulk three-eighths, and by this steam expansively three-eighths more are gained, and not only theory but practice proves that gain on all the Cornish engines. The usual height of steam is sixty pounds above the atmosphere, but if the boilers could be made safe against explosion and work with much higher steam, the advantages would almost exceed limit. The accidents that have taken place by explosion, do not appear to be from overloading the safety-valve, but from overheating the boiler, because low pressure boilers have often exploded, and this generally takes place immediately on setting the engine to work. When the boiler is under water guage it must be red hot, and while the engine is standing, the water in the boiler is still, but the moment that the engine starts, the sudden escape of steam from the boiler to the cylinder causes a great ebullition of the water, and splashes it over the red hot sides, which instantaneously generates a superabundant quantity of steam more than the strength of any boiler, however strong, can sustain; because one pound of melting iron will boil three pounds of water, therefore the red hot tubes of a boiler, to be suddenly cooled by water splashing over them, would immediately generate a hundred times as much steam as the space of the boiler would contain: therefore, while the feed is so uncertain, and the height of water fluctuates so much in the boiler, no permanent safety can be relied on, however light the safety-valve may be loaded, or strong the boiler may be. Boilers fed with salt or even foul water are dangerous; they are often incrusted with salt, repeatedly heated red hot, and quickly reduced in sub-

stance and strength. To prevent the salt accumulating, a constant stream of boiling water is ejected from, and cold water in its stead injected into the boiler, which occasions a constant fluctuation in the height of water in the boiler, and requires a constant caution in the engineer to prevent mischief. A proof that boilers do not explode from the regular working pressure of steam, is by the portable gasholders of one-sixteenth of an inch thick and ten inches diameter being regularly charged with thirty atmospheres, or 450 pounds to the inch, without accident: and though this pressure is not one-half the pressure that the theory of the strength of iron would bear, yet boilers have often exploded, though the safety-valves have never been loaded with one-eighth part of the pressure of the gas holders, or one-sixteenth of the pressure of the theory of the strength of iron in proportion to the strength and diameter of boilers, when compared with gas holders; therefore, perfect safety never can be relied on under the present regulations. To remove these serious evils, save fuel, and give a considerable increase in the power of engines with less space and weight, I have made an entire new engine, both in principle and arrangements. The fire-place, boiler and condenser are formed of six wrought iron tubes standing perpendicular on their ends, encircled the one within the other for the purpose of safety, and to occupy little room, also for keeping the boiler to one constant gauge, with fine distilled water, permanently working without loss, by condensing the steam and never suffering it to escape out of the engine, but returning it from the condenser back again into the boiler every stroke of the engine by a force pump; and where an engine is perfectly tight, it would work for ever without a replenish of water. But, to supply, leaks a small evaporating apparatus is used for supplying the deficiency with distilled water, which effectually prevents any fluctuation in the height of water in a boiler or collecting sediment, and an impossibility of ever getting the boiler red hot, there being no space for the water to fly to out of the boiler but into the condenser: and this is so small, that if, by any means, the force pump did not return the water regularly from the condenser to the boiler, the space in the condenser, by taking one inch in depth of water out of the boiler, would fill and glut the condenser so, that the engine would stand still, and, as the water cannot diminish, it does not requre a large quantity of water, or water space in the boiler, so necessary in other engines, to guard against fluctuation in the feed, and prevent the boiler becoming red hot. The boiler being considerably less, the strength and room will be increased, and, never getting hot, the engine might be worked with much higher steam; if so high as the gas-holders are charged with, the theory gives a saving of fuel, weight and room, over low pressnre engines of sixteen to one, without a supply of water. I state this to show the probable advantages that will arise from this new engine. For my engine to be one hundred horse power, to raise sufficient steam, the fire tube must be three feet diameter, which would give the boiler a diameter of three feet eight inches; and that a half inch thick, according to the theory of the strength of iron, would sustain a pressure of 1,736 pounds to the inch, which is four times as great as the gas-holders are charged with, and thirty-two times the pressure that the high pressure engines work with at present, which is still farther proof that the explosions have been solely occasioned by the boilers being under water gauge, and heated red hot. If, after boilers have been forced on their trial by cold water pressure, to stand ten times the pressure that they are to be worked at, and a boiler should happen to explode, the shock would be first received by the next surrounding

tube, and so on for six successive surrounding tubes; each space between the tubes would admit the steam to escape gently up the chimney without harm, and the outside tube that encircles the whole, might be made of three quarters of an inch thick, so that it would put injury from explosion beyond possibility. The arrangement of this new engine embraces every advantage that can be wished for; safety, saving of fuel, lightness, little room, cheapness, simplicity, and nearly independent of water, it can be made applicable to any purpose, and, much more effectual than horse power, the first cost of erection far less than a quarter the cost of horses, for the duty performed, independent of the difference of expense between coals and horse feed, because a one horse engine will, by constant work, perform the work of four horses every twenty-four hours. For breaking up and tilling large commons, very little establishment will be required. Another great national advantage will be gained, by the whole of the kingdom being abundantly supplied with fresh fish, as it will be in the power of every fishing-boat to get a small engine, and bring fish to market all round the coast while fresh, independent of wind: this may be carried by locomotive engines, in a few hours, to the interior of the country. Besides, every merchant ship will be propelled by steam, as an engine of ten tons weight on the deck, occupying very little more room than a ton cask, would propel a ship of 500 tons five miles per hour with sixpence worth of coals, and will also pump the ship, weigh the anchor, and take in and out the cargo. The principles of the leading power being matured, all the applications will soon follow.

Davies Gilbert, esquire, a member of the committee, examined.

Have you paid any attention to the general nature and advantages of wheels and springs for carriages, the draughts of cattle and the form of roads? I paid considerable attention to it during the sitting of the committee of this House about twenty years ago, of which Sir John Sinclair was chairman; and I then drew up some observations on the nature of wheels and springs on roads, which, with some alterations, I printed in the eighteenth volume of the Journal of Sciences, and which I would beg to deliver into the committee as the result of my observations on the subject.

[*The same was read as follows:*]

"Taking wheels completely in the abstract, they must be considered as answering two different purposes.

"First, they transfer the friction which would take place between a sliding body and the comparatively rough uneven surface over which it slides, to the smooth oiled peripheries of the axis and box, where the absolute quantity of the friction as opposing resistance is also diminished by leverage, in the proportion of the wheel to that of the axis.

"Secondly, they procure mechanical advantage for overcoming obstacles in proportion to the square roots of their diameters, when the obstacles are relatively small, by increasing the time in that ratio, during which the wheel ascends; and they pass over small transverse ruts, hollows or pits, with an absolute advantage of not sinking, proportionate to their diameters, and with a mechanical one as before, proportionate to the square roots of their diameters: consequently, wheels thus considered, cannot be too large; in practice, however the are limited by weight, by expense, and by convenience.

"With reference to the preservation of roads, wheels should be made wide, and so constructed as to allow of the whole breadth bearing at once; and every portion in contact with the ground should roll on it without the least dragging or slide; but, it is evident from the well-known properties of

the cycloid, that the above conditions cannot unite unless the roads are perfectly hard, smooth and flat; and, unless the fellies of the wheels, with their tiers, are accurately portions of a cylinder. These forms, therefore, of roads and of wheels, are the models towards which they should always approximate.

"Roads were heretofore made with a transverse curvature to throw off water, and, in that case, it seems evident that the peripheries of the wheels should, in their transverse sections, become tangents to this curve, from whence arose the necessity for dishing wheels, and for bending the axes, which contrivances gave some incidental advantage for turning, for protecting the nave, and by affording room for increased stowage above. But recent experience having proved that the curved form of roads is wholly inadequate for obtaining the end proposed, since the smallest rut intercepts the lateral flow of the water; and that the barrel shape confines carriages to the middle of the way, and thereby occasions these very ruts; roads are now laid flat, carriages drive different over every part, the wear is uniform, and not even the appearance of a longitudinal furrow is to be seen. It may, therefore, confidently be hoped that wheels approaching to the cylindrical form will soon find their way into general use.

"The line of traction is mechanically best disposed when it lies exactly parallel to the direction of motion, and its power is diminished at any inclination of that line in the proportions of the cosine of the angle to radius. When obstacles frequently occur, it had better perhaps receive a small inclination upwards, for the purpose of acting with most advantage when those are to be overcome. But it is probable that different animals exert their strengths most advantageously in different directions, and therefore practice alone can determine what precise inclination of this line is best adapted to horses, and what to oxen. These considerations are, however, only applicable to cattle drawing immediately at the carriage; and the convenience of this draft, as connected with the insertion of the line of traction which continued, ought to pass though the axis of the wheels, introduces another limit to their seize.

"Springs were in all likelihood applied at first to carriages, with no other view than to accommodate travellers. They have since been found to answer several important ends. They convert all percursion into mere increase of pressure; that is, the collision of two hard bodies is changed by the interposition of one that is elastic, into a mere accession of weight. Thus the carriage is preserved from injury, and the materials of the road are not broken: and, in surmounting obstacles, instead of the whole carriage with its load being lifted over, the springs allow the wheels to raise, while the weights suspended upon them are scarcely moved from the horizontal level. So that, if the whole of the weight could be supported on the springs, and all the other parts supposed to be devoid of inertia, while the springs themselves were very long, and extremely flexible, this consequence would clearly follow, however much it may wear the appearance of a paradox, that such a carriage may be drawn over a road abounding in small obstacles without agitation, and without any material addition being made to the moving power or draft. It seems, therefore, probable, that, under certain modifications of form and material, springs may be applied with advantage to the very heaviest wagons, and consequently, if any fiscal regulations exist, either in regard to the public revenue or to local taxation, tending to discourage the use of springs, they should forthwith be removed.

"Although the smoothness of roads, and the application of springs are beneficial to all carriages, and to all rates of travelling, yet they are eminently so in cases of swift conveyance, since obstacles, when springs are not interposed, require an additional force to surmount them beyond the regular draft, equal to the weight of the load multiplied by the sine of the angle intercepted on the periphery of the wheel between the points in contact with the ground and with the obstacle, and therefore proportionate to the square of ~~its hei~~ght; and a still further force, many times greater than the former when the velocity is considerable, to overcome the inertia, and this increases with the height of the obstacle, and with the rapidity of the motion both squared. But, when springs are used, this latter part, by far the most important, almost entirely disappears, and their beneficial effects, in obviating the injuries of percussion, are proportionate also to the velocities squared.

"The advantages consequent to the draft, from suspending heavy baggage on the springs, were first generally perceived about forty years since on the introduction of mail coaches; then baskets and boots were removed, and their contents were heaped on the top of the carriage. The accidental circumstance, however, of the weight being thus placed at a considerable elevation, gave occasion to a prejudice, the cause of innumerable accidents, and which has not, up to the present time, entirely lost its influence; yet moment's consideration must be sufficient to convince any one, that, when the body of a carriage is attached to certain given points, no other effect can possibly be produced by raising or by depressing the weight within it, than to create a greater or less tendency to overturn."

The extensive use of wagons suspended on springs, for conveying heavy articles, introduced within these two or three last years, will form an epoch in the history of internal land communication not much inferior perhaps in importance to that when mail coaches were first adopted; and the extension of vans, in so short a time, to places the most remote from the Metropolis, induces a hope and expectation that, as roads improve, the means of preserving them will improve also, possibly in an equal degree; so that permanence and consequent cheapness, in addition to facility of conveyance, will be distinguished features of the Macadam system.

I have made some further remarks, which I would beg to deliver in also, tending to point out particularly the advantage of steam conveyance when the rate of travelling is great: I would beg to add, that it appears to me extremely difficult to lay down any general rule which would be applicable to all situations and all roads, inasmuch as they vary with the nature of the materials: that up to a certain weight, proportionate to the corresponding width of the wheel, it is probable that the injury to any road may be very little, but that beyond a certain weight, compared again with a corresponding breadth of the wheels, the materials would be entirely crushed, and the road totally destroyed. Therefore it follows, that even on all roads there must be a limit to the weight of carriages, as it is quite impossible that a wheel of enormous breadth could bear uniformly on all its surface. For instance, where trains of artillery are drawn over roads, the excess of their weight beyond what materials are capable of sustaining, has been found sufficient for grinding them to powder. "The slow conveyance of heavy weights may perhaps be effected by steam on well-made and nearly level roads, so as to supersede the use of horses; but steam power is eminently useful for producing great velocities. It was last year determined by the Society of Civil Engineers, after much inquiry and discussion, that the

expense of conveying carriages drawn by horses was at its minimum when the rate of travelling equalled about three miles an hour, and that expense increased up to the practical limit of speed, nearly as the velocity; including the greater price of horses adapted to swift driving, their increased feed and attendance, the reduced length of their stages, and, with every precaution, the short period of their services. On the contrary, friction being a given quantity as well as the force requisite for impelling a given weight up a given ascent, the power required for moving steam carriages on a railway remains theoretically independent of its speed, and practically increases but a very little, in consequence of resistances from the atmosphere, slight impacts against the wheels, inertia of the reciprocating piston, &c. The expenditure of what I have termed efficiency, is, as actual force, multiplied by velocity, and the consumption of fuel in a given time will be in the same proportion, but the time of performing a given distance being inversely as the velocity, the expenditure of fuel will theoretically be constant for a given distance, and very nearly so in practice. The power requisite for moving bodies through water is in the opposite extreme; here, the mechanical resistance of the fluid increases with the square of the velocity, as do the elevation of the water at the prow, and its depression at the stern. The oars or paddles must therefore preserve a constant ratio to the velocity of the vessel; and the force applied will consequently vary as the squares of the velocity; and the expenditure of efficiency being as the force multiplied by the velocity; the consumption of fuel will be as the cube of the velocity in a given time, or as the square of the velocity on a given space; and I have ascertained from the records of voyages performed by steam vessels, that the law is nearly correct in practice: hence the great power required for such steam vessels as are constructed not merely for speed, but also to set at defiance the opposition of winds and seas; while, on the contrary, a very small power will be found sufficient for moving ships of the largest dimensions through the water, at the rate of two or three miles an hour, when their sails are rendered useless by continued calms."

Mr. *Nathaniel Ogle,* called in, and examined.

What is your profession? I have no profession; I am pursuing the introduction of locomotive engines on common roads.

Have you invented any carriage of this description actually now in practice? Yes, partly so.

Have you run your carriage for any length of time on public roads? About 800 miles, or rather more, over roads of various descriptions, and up lofty hills.

Will you describe, generally, the nature of your carriage, and of any improvements you have made since you first turned your attention to the subject? The object in all locomotive vehicles is to obtain a mode of generating steam that shall give the command of a sufficient power, under all varying circumstances to be met with on the common roads. We have obtained that desideratum, by combining the greatest heating surface in the least possible space, with the strongest mechanical force, so that we work our present boiler at 250 lbs. pressure of steam on the inch, with the most perfect safety. Our experimental vehicle, weighing about three tons, or rather more, we have propelled from London to Southampton, and on the roads in the vicinity of Millbrook, at various speeds. The greatest velocity we obtained, over rather a wet road, with patches of gravel upon it, was

between 32 and 35 miles an hour, and might have been continued under similar circumstances, and we could, on a good road, have increased that velocity to 40 miles. We have ascended a hill with a soft wet bottom, rising one foot in six, at rather a slow rate. We have ascended one of the loftiest hills in the district near Southampton, at 16½ miles an hour. We have gone from the turnpike gate at Southampton to the four mile stone on the London road, a continued elevation, with one very slight descent, at a rate of 24½ miles an hour, loaded with people. The locomotive vehicles used on the Liverpool and Manchester railroad would not go at three miles an hour on a common level road, and would not ascend any hill; and on account of the diameter of their boilers, cannot, scientifically speaking, be considered safe. The vehicle is under perfect control in every respect. No accident from explosion can take place. We have had whole families of ladies, day after day, out with us in all directions, and who have the most perfect confidence. We are now upon the point of establishing a factory where these vehicles will be made in numbers; and a great many are already required by coach proprietors, carriers of merchandise, and others, for their use on the public roads. Railroads, excepting in very peculiar situations, are behind the age; and it is my decided opinion, that those who embark capital in constructing them will be great losers.

Will you describe the form of your boiler? The base of the boiler and the summit are composed of cross pieces, cylindrical within, and square without; there are holes bored through these cross pieces, and inserted through the hole is an air tube. The inner hole of the lower surface, and the under hole of the upper surface, are rather larger than the other ones. Round the air-tube is placed a small cylinder, the collar of which fits round the larger aperture on the inner surface of the lower frame, and the under surface of the upper frame work. These are both drawn together by screws from the top; these cross pieces are united by connecting pieces, the whole strongly bolted together, so that we obtain in one-tenth of the space, and with one-tenth of the weight, the same heating surface and power as is now obtained in other and in low pressure boilers, with incalculably greater safety. Our present experimental boiler contains 250 superficial feet of heating surface in the space of 3 feet 8 inches high, 3 feet long, and 2 feet 4 inches broad, and weighs about 800 weight. We supply the two cylinders with steam, communicating by their pistons with a crank axle, to the ends of which either one or both wheels are affixed as may be required. One wheel is found sufficient, excepting under very difficult circumstances, and when the elevation is about one foot in six, to impel the vehicle forward.

Have you taken out a patent for this invention? We have, in the name of William Altoft Summers and Nathaniel Ogle.

You state that the weight of that carriage is about three tons or more—is that independent of the necessary load? That will include the coke and the water, but not the passengers.

Have you any peculiar means for rendering explosion impossible? Yes; the cylinders of which the boilers are composed are so small as to bear a greater pressure than could be produced by the quantity of fire beneath the boiler, and if any one of these cylinders should be injured by violence, or any other way, it would become merely a safety valve to the rest. We never with the greatest pressure, even, burst, rent or injured our boilers, and have not once required cleaning after having been in use twelve months.

Is the connexion between your different cylinders so perfect, that there is no danger of the steam collecting in one particular point of it? There is a perfectly free communication, and not the least danger to be apprehended.

Have you one or two safety-valves! Two.

At what pressure do you usually work your carriage? Two hundred and forty-seven pounds on the square inch of the boiler, but we have worked it at a greater pressure than that.

To what pressure do you usually weight your safety-valve? Two hundred and forty-seven pounds.

Then you travel always on the lift? Yes; we are always glad to see our steam blowing off, and when our fire is even moderately good, it is always blowing off, even up the steepest hills, proving an excess of power.

Does that create any annoyance to passengers along the road? None whatever; the waste steam is carried round a double casing of the fire place, then brought over the surface of the fire where some portion is consumed, and the rest passes off through a very small chimney in an aeriform state.

Do you use coal or coke? Soft and good coke which easily ignites and burns rapidly.

You have not any annoyance then to passengers from smoke from your carriages? None, whatever; there is no appearance of smoke, except on lighting the fire with wood, which is necessary to ignite the coke.

That takes place before you start? Yes; but even that will not be necessary when every thing is arranged.

You state that your carriage is under the most perfect control? Perfect.

Supposing you were going at the rate of ten miles an hour on a level road, in what number of feet do you suppose you could entirely check the carriage? It would be difficult to state precisely the number of feet, but certainly in a less space than you could stop a pair of carriage horses going with the same weight attached to them. I have no hesitation in saying, that a steam vehicle is safer in every respect han one with horses, that it is under more complete management at the same velocities and with the same weight, that it is more easily controlled, and that none of the accidents from fractious horses can take place with steam carriages.

Do you find that horses are generally frightened by passing your carriage? Very few indeed; persons usually alarm their own horses (the animal being quickly subject to alarm) either by dismounting or patting them, and thus anticipating apprehension.

What rate of toll has been charged on your carriage in the neighborhood of Southampton? None, whatever. I have paid near London, when trying experiments, a shilling or two, and I made no inquiry. I remember going out of London, throwing one man a shilling, and another two, being too much occupied to trouble myself about the matter.

You pass through turnpikes in travelling round Southampton? Yes.

What is the reason they have not charged you? I do not know, unless they had the good sense to see that we rather do good to the road than injury.

Do you know on what authority they levy tolls on carriages? I know of only two instances in which they have been levied on steam carriages, one at Hammersmith bridge, and the other at Cambridge heath, near Hackney.

If toll collectors at Southampton abstain from demanding tolls, is it not because they had not authority to demand them? I do not know their motive.

You think that the toll collector is so interested in the good state of the road, that he would abstain from demanding toll on that ground? I think

that if they have contracted to keep the road in repair, they would be glad that steam vehicles should run upon that road in preference to carriages drawn by animals; because the wheels of steam carriages, if the tires are of a proper breadth, act as rollers.

Do you know whether the toll collectors in general, contract for keeping the road in repair? I do not know.

Do you know any instance of it? No, I do not.

Have you heard any complaint by contractors of the injury done to roads from your carriages? No.

Nor from the surveyors of roads? No.

What is the breadth of the tires of your wheels? About three inches.

Could you increase the tire of your wheels without inconvenience? Certainly.

To what breadth? With a given weight there might be given breadths; in my opinion a vehicle carrying four tons weight, the engine itself weighing three tons, should have a tire about four inches and a half in breadth, a flat tire, not a round tire, and the wheels should be cylindrical. It is decidedly to the interest of steam coach proprietors to have the tires broad, as the wheels have a diminished tendency of sinking into the road.

Should they be increased according to the weights? Yes, but I do not think that we have knowledge enough to speak precisely on that subject, and to go into minute details as to the exact breadth which should bear a given weight.

Taking either an increased or a diminished weight, what would be the increased or diminished breadth of wheels which you would recommend?

I am not prepared to answer that minutely.

Is it your opinion, that, in case they exceed three tons weight, that wheels, three inches wide, improve the road, passing with the velocity they do? Certainly; the velocity has nothing to do with the wear of the road.

How many wheels have you? Our present carriages have only three, so that the centre wheel rolls that portion of the road which has been cut up by the action of the horses' feet.

Is it of the same breadth as the two hind ones? It is broader, being four inches and a half.

Is the centre wheel a guiding wheel? It is.

What portion of weight is upon that as compared with the others? That must vary a little, but generally about one-third.

Is yours a coach? No, it is a treble-bodied phæton.

How many passengers have you carried when you have gone at the rates you have described? I think I have seen nineteen; weight is of no importance to a steamer.

Taking the weight of your carriage, with the engine, at three tons, what weight do you suppose that you could carry at the rates you have spoken of? Between three and four tons, very well.

Besides its own weight? Yes.

Doubling its own weight? Yes; twenty people will weigh more than a ton and a half.

For what distance do you travel without taking in water?—We can increase our capability to a great extent; at present, we carry about seven hundred weight of water; it lasts about fourty minutes; that depends on the quality of the road.

How much coke? The quantity we carry is according to the distance we wish to go.

What weight of fuel would you think it necessary to take in, to go one of your averages stages? Three bushels.

How much does a bushel weigh? That is difficult to answer, coke differs in its weight; the average weight is about forty pounds a bushel.

What proportion of injury do you think one of your steam carriages does to the road in comparison with the injury done by a coach drawn by horses proceeding with the same velocity? Not one half; first of all they receive no injury from the feet of the horses; a horse must have something to hold by, and the action of a horse's foot is to scrape and dig up the ground. Vehicles drawn by horses of equal weight, have usually narrower wheels, which must increase the injury done to the road.

Are your wheels dished, or are they cylindrical? Cylindrical, with flat tires.

What are the diameters of your propelling wheels? We have generally used them about six feet; those we have now are about five feet six.

Have you changed the diameters from experiment, from finding the smaller diameter more convenient? From finding some wheels with the spokes cut through, whether intentionally by the workmen, or from mere neglect, we could not tell; but they were merely reduced from six feet to five feet six.

For a carriage calculated to carry eighteen persons, what would be the length, and what the breadth? I think that our next will measure eighteen feet six; that is not so long as a carriage with two horses: the breadth six feet nine inches between the wheels.

During the course of your experience, have you met with any accident, such as the breaking of your machinery? None whatever of any denomination; not one bolt, not one screw has ever given way, during a period of twelve months, and under circumstances which would have utterly destroyed any other carriage, and very much to the surprise of engineers, who are sadly uninformed on all points relative to steam coaches, and have never advanced their success.

In the improvements you are now engaged upon in your carriage, are they relative to the size and weights of the different parts, or merely in the conveyance of the goods and passengers? They are more in improving slight details; the power we have beyond all question to propel vehicles of any weight, at any required velocity.

Have you made many experiments as to the size of your cylinder? We have made several experiments.

In reference to the usual velocity you require, and the weight you have to carry, what do you find the most advantageous size of cylinder? The larger the cylinder, certainly, the better; but were I to give definite answers to such questions, it would be giving too much information to those opposed to us.

What is the greatest weight that any steam engine you have ever built is capable of carrying ten miles an hour? About three tons, in addition to its own weight. The majority of the London engineers treated our opinions, founded on the laws of nature and experiment, with contempt and ridicule, and were amazed at witnessing the vigor of our engines, and the velocity with which we left the factory in Cablestreet, Whitechapel, and proceeded towards Shouthampton.

Have your ever ascertained that that carriage, when loaded, weighs six tons? No, never.

What was the greatest weight you ever weighed? We never weighed it at all. I can only speak from conjecture. I have seen nineteen persons on it, and seven cwt. of water.

At what rate did you travel with that load? We went with that load up a considerable ascent, about thirteen miles from Southampton; I should think, about from a quarter to half a mile. We travelled about ten miles an hour.

How did you ascertain that rate—did you make accurate observations at the time? We know pretty accurately, by observation, at what rate we are going; but we can ascertain with the greatest minuteness, by knowing the number of revolutions made by a wheel of a certain diameter.

When you were conveying those nineteen persons, how many horse power do you suppose was exerted by your machinery? Nearly twenty horse power.

You have stated that your carriages do not do injury to roads, but are rather a benefit; subsequently you have said that your carriages did not do half the injury of common carriages? Yes; if the tire of the wheel was very broad, it would be no injury.

Do you know the ordinary breadth of the tire of a stage coach wheel? About two inches or two and a quarter, varying a little.

Do you know the weight of a stage coach, with its complement of eighteen passengers? Three tons.

What particular coach do you refer to? The Telegraph from London to Southampton, with its full load, has been reported to me, by its proprietors, to weigh about three tons.

What would be the weight of your machine when loaded? Three tons, besides its load.

What do you suppose the nineteen passengers weighed? A ton and a half certainly.

The breadth of your tire is three inches? Yes.

From your observation of the effect of a coach weighing three tons, and a two and a quarter inch tire going along a road, seeing the impression made upon the roads, and witnessing your own carriage weighing four tons and a half, with a three inch tire, what is the relative indentation or injury done to the road? Not greater, as far as I have ever been able to observe.

Is it as great? I think not as great.

Independent entirely of the injury that the four horses do to the road? Just so. Independent of that entirely.

Can you suggest any mode by which tolls shall be fairly charged on steam carriages? I should say by their weight, with a deduction in favor of the steam engines, inasmuch as they do not the same degree of injury to the road as a vehicle drawn by horses.

Do you think that the injury done by four horses on a road is greater than the injury done by the four wheels of the same carriage? Decidedly.

Upon what data do you state that opinion? Because the animal must hold on as he goes; if he has a great weight behind him, he must hold tighter than if he merely carries his own weight. I do not know the number of strokes that a horse's foot must have gone in an hour, but it is a great number, and where there are four horses, those must be multiplied; and this, on a road moistened by the rain, must make great indentations, and tear up the surface: the transit being continuous, the road must suffer more than from the mere pressure of the tire over it.

Do you state that as your opinion merely, or as the result of your observation and practice? As the result of my observation and practice, and also from the deductions of reason.

Where have you made those observations? In going about on horseback in my own steam vehicle, and my own carriage, I have observed the manner in which the road has been cut up. I have also observed the road, after it has been passed over by a steam vehicle, and have seen that part of the road we found injured by the horses' feet rolled over by the middle wheel.

In what state was the road at the time? Rather wet.

Were the materials recently laid down, or consolidated? There were patches of gravel; and there the steam carriage was a decided advantage.

Was it of more advantage than the wheel of an ordinary carriage? Yes, decidedly so.

Do you conceive that the injury done by horses' feet is in the wearing of materials, or the displacing materials? In both.

What is the nature of the injury which the wheel does? The wheel always forms for itself a hill, and that hill is in exact proportion to the indentation.

Do you mean to say that the hill is formed by the displacing materials? Yes there is a line, of the materials of which the road is composed, on both sides of the tire.

If a road is properly constructed, will that take place? The harder the road, the less the indentation.

Have you paid much attention to the construction of roads? Not much.

Will you state more definitely the nature of the injury you have seen in regard to the effect of the horses' feet, in comparison to that of the wheels of carriages? First of all they displace at every blow, they tear up, and throw the surface behind them; whereas the wheel only rolls as it goes, and throws some portion on both sides of it, if the road is soft.

Do you know from your own knowledge how much the crust of an ordinary road round London will bear? No; it depends so much upon the nature of the road.

Mr. *Alexander Gordon*, called in, and examined.

Are you an egnineer? I am.

Have you had much experience in the propelling carriages on common roads by steam? My principal experience in that has been whilst observing what Mr. Gurney has done. I have also been connected with locomotive engines, for which my father took out patents in 1822 and in 1824; and also with an engine that Mr. Brown attempted to propel by a gas vacuum engine in 1824, 1825, and 1826. I have not had time to prepare a drawing, but I have made a small sketch of two distinct patents (*producing the same*) which my father had in 1822 and 1824. The one in 1822, was a machine, with a small high pressure engine in a drum; as the drum advanced with a rolling motion, it moved, before it, a carriage body on two wheels, attached to the front of the large rolling drum. Subsequently, in 1824, my father discontinued his former plan, and took out another patent, in which his object was to substitute propellers instead of the driving wheel: for that purpose, he had propelling legs in the middle of the locomotive engine, similar to horses' legs and feet, working through the bottom of the body of the carriage against the ground, thus propelling the carriage onward. Mr. Gurney's progress in 1826 and 1827, showed clearly that this arrangement was not necessary in

every case, but that one of the wheels of the carriage, when attached to the steam engine, had a sufficient hold of the ground to give progressing motiou to the carriage without using propellers; and the introduction of that invention has subsequently been given up by me in consequence.

Have both the plans you have given in been given up? Both. They were given up from prudential motives on my own part, as it was an expensive business to proceed with them. Mr. Gurney had made such great advances, that it would have been throwing away money I think to have gone on further with them. I found that the propelling feet, shown in the middle of the engine, do more injury to the roads than the propelling wheels.

Have you been engaged in running stage coaches? I was engaged in running a stage coach with horses four years ago; and since this committee commenced their examination, I have been making some calculations as to the comparative wear and tear of the road by horses' feet and coach wheels; and I consider that the tear and wear of the horses' shoes is very much greater than that of the tires of the wheels. I know it to be so. A set of tires will run 3,000 miles in good weather, or on the average 2,700 miles, while a set of horses' shoe will travel only 200 miles. Take the square inches of the rubbing surface, I think the rubbing surface of the wheel, on an ordinary road, to be somewhere about sixteen square inches; I am taking a gravelly road.

Do you mean to say that if a coach was standing still, there would be a segment of the wheel of eight inches touching the ground? On a gravelly road, with a dished wheel, it is about that; and I take the average of sixteen square inches, because all tires are not limited to two inches width: some of them are a little more; I take sixteen inches as the standard on the average quality of roads.

You state that eight inches of the wheel are imbedded in the road in ordinary cases? That is the fact. I took the whole together at the average. With the front wheels it would not be so much, on all occasions, as on the hind wheels. I take the average, allowing for this variation.

Do you give this answer from actual experiments? From observation.

Having measured that part of the wheel which touches the road? I cannot say that I have put my rule to it; but I mean to say a segment of eight inches is pretty accurate. If it is on a perfectly hard road, in dry weather, the road will almost be a mere tangent to the circle; but on a soft road, in damp weather, the wheel will make more or less of a rut, and the average depth of the rut will give the average for the segment.

Will you give the proportion of surface for the horses' feet? I think twelve square inches superficial for one horse-shoe. I cannot say that I have measured it.

What is the weight of the carriage which you say imbeds itself eight inches? I take the weight of the ordinary post coaches, when fully loaded, to be somewhere about three tons. I principally rest my opinion, as to the comparative tear and wear, upon the wear of the horses' shoes when compared with the wear of the tires. A horse, after a run of 200 miles, must be shod; and after a run of 3,000 miles, in dry weather, a coach must have new tires.

From thence you infer that the wear of the two is in proportion to those numbers? I think it must be thereabout; that is, setting aside altogether for the present, the consideration that the horses' movement is a series o thumps and picks, while the wheel it a roller.

Is not the iron of the wheel thicker than that of the horses' shoe? Yes; to keep the wheel firm.

Do you not infer, from the action of the horse's hoof upon the road, that the injury would be great in proportion? I think that the action of the horse's foot on the ground is more destructive to the road: there is more tear and wear to the road by the horse's shoe than by the tire. In rolling two tons along the ground, on four wheels, there will be no less damage done than by driving four horses without drawing any thing after them along the same ground.

Have you made any observations as to the relative wear of the shoes of riding horses compared with those of horses employed in carriages? No; I now speak from circumstances which came to my knowledge when I was connected with running a stage.

Have you had an opportunity of comparing the wear of the wheels of a steam carriage with the wear of the wheels of a carriage, supposing they run equal distances and carry equal weight? I have seen Mr. Gurney's proceedings from the beginning to the present time, and in riding with him, I have very narrowly observed the driving wheel to see whether it ever made a surd, (that is to say) made a slip or missed its hold of the ground; and that has so seldom happened, that I do not think it can do much more injury than any other wheel, indeed I might say none; if it does, it is very trifling.

You speak of the propelling wheel? Yes.

Do you know the weight of Mr. Gurney's carriage? I know the weight of Mr. Gurney's carriage from having been told. I take the weight of Mr. Gurney's present locomotive engine when it carries six or eight persons, to be nearly as heavy as an ordinary four horse carriage without the weight of its horses, that is, about three tons with coke, water and passengers.

Are you speaking of the comparative injury to the roads done by Mr. Gurney's carriage and a four-horse coach? Yes.

Which do you think does most injury to the road? I should think it must be the same thing, carrying a great weight on any four wheels of equal diameters and surfaces: it will amount to the same thing.

Does not that suppose that the tire is of the same width? I take the tires to be the same.

That is independent of the four horses? Yes.

Then the injury done by the four horses is in addition? Yes.

Have you observed what the proportion is of the damage done by four horses drawing a coach, and the four wheels of a coach? I cannot say that I have made any observation upon that further than the tear and wear of the shoes, and the tire. I have seen the ruts in a narrow road and the horses' path between them; viewing these and viewing the towing path on the side of a canal and between the rails of railroad, I should think that the horses do fully more harm than the wheels.

Do you think that the action of the horse's feet on a towing path will do more injury than on a road? Yes; but the action of the horse's feet on a towing-path is not quite the same as when he is carrying a weight or pulling a weight directly after him. The horse hauling on a canal has a motion sideways, and leans to the side farthest from the boat, platting his feet: this is a more destructive action than that of horses' feet on a road.

Have you found that there is any tendency to slip in Mr. Gurney's carriages in going up a hill covered with new stones? When the surface of the road is not firm, there is a tendency to slip; and when I said there was

merely a fraction more of injury done by that wheel than by the others, I was taking such cases into account.

Do you think that the injury that steam carriages do to the roads will be exactly in proportion to their different weights, taking the same breadth of the tire? I cannot state the proportion; if you increase the weight, you must increase the breadth of the tire: at different speeds, the injury will differ.

Taking the same breadth of tires, and the same velocity, do you conceive the injury to the road increases in exact proportion to the weight; for instance, that a steam carriage of two tons will do only half the injury that a coach of four tons would do? I do not know that it will be exactly in these proportions; but it will be somewhat similar.

Then supposing that a steam coach carrying two tons, had tires of a breadth of three inches, and that a steam coach carrying four tons had the tires of the wheels of the breadth of six inches; do you think that the injury would be proportionate? I think that there would be nearly the same amount of injury.

Suppose you increase the weight so as to break through the crust of the road? If you put a very heavy weight, you will break the crust of the road altogether, no doubt.

Do you think that could be obviated by increasing the breadth of the tire of the wheel? To a certain extent; but you may increase the weight so much as to pulverize the material of the road, even with a broad tire.

Have the observations you have made been founded on actual experiment or not? It is on observation; I have observed the action of Mr. Gurney's wheels very narrowly on the roads, because I was interested in another patent that was to introduce propellers in the middle of the locomotive engine as shown in the drawing produced.

Have you observed them under different ascertained weights? No great variety.

Upon an ordinary road, is the injury done by a stage coach or by a steam carriage so great as to be apparent at each time that carriage travels along the road? Whenever you see a mark left by a wheel, you are entitled to say there is an injury done to the road to the extent of the rut.

Do you state that if it is merely a mark on the soft surface of the road? Yes, from the wheel being at all imbedded in the soil; the water gets in and soaks its way through. If it is in frosty weather, the water and the damp get down, and the alternate freezing and melting destroys the road.

In an ordinary road, is the impression of the wheel of a stage coach upon the solid surface of the road so great as to make the injury apparent every time the carriage passes over it? It is apparent to me, because, wherever there is a mark upon the road, there is a consequent injury.

Whether that mark is merely the impression of the wheel on the soft mud or dust, or by crushing the materials? Wherever the road is damp, the consequence of the mark, however slight, tends to destroy the road.

Do you mean whether on the soft mud on the road, or on the solid substance? The road must be destroyed to some extent; I do not say that it is perceptible. If you put out of consideration the surface, the mere mud, it is not perhaps perceptible at the time, but there must be tear and wear going on on the road, or it will last for ever. I do not now talk of the action of the elements.

On what data do you state that the steam carriage does not do more injury

than the wheels of a stage coach? Because it does not make a deeper rut.

Does either of them make a rut? If you suppose the road to be a concrete mass, and that there is merely a little mud and dust on the top of it, I cannot prove that a four horse coach does any perceptible injury to that road. I will say also a steam carriage will, in a similar case, do no perceptible injury to it.

Of course, if the road was composed of solid rock, you would not be able to tell whether a coach of any description had gone over, there being no mark left, but talking of ordinary turnpike roads, should you be able to trace the indentation that coach made? Yes.

Would you not be able to do the same with the steam carriage? Yes; there are some roads in England, a part of the Holyhead road, for instance, so well made that you cannot trace any vestige of injury done in good weather. A part of Mr. Telford's road there is a concrete mass.

Do you know whether that road has ever been mended since it was first made? I suppose it has.

Should you not say that the injury done to the road by a carriage passing over it, depends greatly on the state of that road, whether damp or dry, or otherwise? Certainly.

Are there any states in which a road is placed in which no injury is done by a carriage passing over it—take the case of a hard frost for instance? No perceptible injury is done in that case, if the road is so hard that the wheel makes no mark upon it. But where the road is at all soft, and when the wheel sinks into that road, it must destroy the road: if it be merely in mud on the surface of the road, it is making a cistern to hold a puddle of water.

The greatest injury done to the road, will be just after the breaking up of a frost? Yes; or in fact after the effect of the frost, the water having got into the interstices, has been frozen and expanded. When it thaws, the road is not so compact, it is soft and pulpy.

That is the state in which the greatest injury will be done to the road by a heavy weight passing over it? Yes.

Have you ever, in such a particular state of the road, observed the injury done by a stage coach drawn by horses, and that by a carriage propelled by steam? I have seen the locomotive engine travelling in the month of January, and also the ordinary carriages, and I cannot see that the locomotive engine has done any more injury than an ordinary carriage. The destruction on the road after a frost is much greater than in other cases.

Have you made observation as to the effect on the road by each carriage when the road was in the worst state? I have seen them exactly at the same time and in the same circumstances. In the month of October, when there had been a considerable deal of rain, and the old road to Barnet, down by Stanmore, was very soft in consequence of the rain, I have seen the effect of a locomotive engine, and the effect of the Hemel Hempstead coach running along side of each other, and I consider that there was no difference at that time. I was then watching the action of Mr. Gurney's wheels, and particularly his driving wheel, with that view. I put the horses out of the case

Was there any perceptible difference in the damage done? None, that I perceived.

What are the effects on the wear of the road, by increasing the velocity of the steam carriage? I have not observed that, but it must be less. Suppose you are carrying a weight on a road slowly after a frost, you will break the crust; but travelling at a greater rate over it, it will not have that effect; the frozen crust will remain unbroken.

Have you observed the effect on the road, by increasing the diameter of the wheels? I cannot say that I have seen that.

In Mr. Gurney's carriage, the wheels do not always follow in the same track? Sometimes they do, and sometimes they do not.

Under those circumstances, supposing equal weights on the four wheels, it would be easy for you to observe whether the wear of the fore and hind wheels was the same? I never observed any perceptible difference in the injury.

A considerable proportion of the wear of the road is to be attributed to the atmosphere, without reference to the carriages which pass over it? Yes; the most destructive element in nature is water; and, in the course of the winter, the action of the water that gets sucked up into the road is very bad, and the very washing is also very bad.

Are they many states of the road in which a wide tire is of considerable advantage to the road? Yes.

In the majority of cases do you think the superior width of the tire which the steam carriage has over a carriage drawn by horses, is altogether an advantage or a disadvantage? A wide tire has the advantage upon the average.

And the steam carriage has that advantage over the other? Of late, Mr. Gurney has increased the width of his tire: it was at all times wider, but he has increased it still more.

Does the width of the tire impede the velocity at all? Scarcely in a perceptible degree.

Are you of opinion that a wide tire, under any circumstances, does injury to a road in any state of it? I have made no observation as to its doing an injury.

Complaints have been made that a great inconvenience arises to passengers along the road from the use of these carriages, from the horses being frightened in consequence of the peculiar noise; the smoke, and the letting off the steam? have you seen any inconvenience of that kind? I have seen one case where a gig ran off for about 200 yards, and was then stopped without any accident. I have also seen the same thing happen with a stage coach; it is a common thing with a young shy horse. I have seen Mr. Gurney's coach at work in the barrack yard, in the Regent's park, and have not seen the horses frightened these.

Should you say you have seen a much greater number of cases of horses being frightened and running away attending the use of steam carriages than of common coaches? My experience in steam carriages is limited, and so must be that of every one when compared with the experience had with ordinary coaches. I have seen Mr. Gurney's engines, in going through the streets of London, and I have not seen horses frightened in any case: they may be shy, and prick their ears at it, but they have not started.

Have you turned your attention to the question, how tolls should be fairly charged on such carriages? No.

Mr. *Joseph Gibbs*, called in, and examined.

Are you an engineer? I am.

Were you brought up to that business? I was.

Are you the patentee or proprietor of a steam carriage? I am patentee of a new method of more economically and safely generating steam, which I am applying to steam carriages.

Has it been practically carried into effect in steam carriages? No; I am building steam carriages, one of which is complete. I have been to Cheltenham to see the effect of a carriage there, and travelled nearly 100 miles between Cheltenham and Gloucester, with Mr. Gurney's carriage with that view.

Did you find that any inconvenience arose to the persons travelling upon the roads from Mr. Gurney's carriage? I did not observe any particular inconvenience ; certainly the horses shyed a little. That may be accounted for from too great a quantity of fuel being consumed, which caused too great a smoke and vapor, but that will be reduced as improvements take place.

Have you paid attention to the effect on the roads of Mr. Gurney's steam carriage? I have.

Will you give the result of your observations? I conceive that steam carriages do no injury to the roads further than the carriages at present in use; no horses being applied, there is so much diminution of injury to the road from the horses not being used: the wheels I do not conceive do any more injury than those of a stage coach, supposing them of both the same weight.

Then deducting the weight of the horses, do you conceive that the injury is the same, weight for weight? Precisely.

What opportunity had you of examining the state of the roads after the carriage had passed over? I frequently went in a carriage attached to the steam carriage, passing behind it: my object was to know the right width a wheel ought to be made to obtain sufficient traction, and I never saw any mud displaced which was upon the wheel during its revolution. I particularly remarked the indentations in the tire which will be made in consequence of the wheel coming in contract with the sharp flints upon the road; now if the wheel had slipped, the tire would have been graved or cut into small furrows, but that was not the case: I had the wheels cleaned in order to observe the effect.

Did you go up any hills? The hill going into Gloucester.

At what elevation? That I cannot say exactly; it is a considerable hill.

Do you conceive great improvements will take place in Mr. Gurney's carriage? I conceive great improvements will take place in all steam carriages; that they are in their infancy; that there are not yet sufficient practical data to form a perfect judgment by as to the ultimate shape of the vehicle, arrangement of parts, and weight of machinery.

Have you considered what would be the best mode of charging toll on such carriages? No; I have not yet paid attention particularly to that subject.

Is toll charged on Mr. Gurney's carriage? None was charged while I was there.

Have you seen Mr. Hancock's carriage? I have.

He carries his passengers—he does not draw them? No, he does not.

Do you give the same result as to your experience of the injury from that carriage? Yes; except that Mr. Hancock's wheel is not cylindrical; it is rather conical, and a conical wheel must be more injurious to the roads than an upright one, although, in this case, the wheel being narrow, the difference cannot be very great.

On the principle on which you state that you are forming your carriages, shall you be enabled to diminish the weight greatly? The carriage I am now constructing weighs two tons, without water: it is made stronger, because there are not any practical data yet respecting the parts.

Veneris, 19 *die Augusti*, 1831.

Thomas Telford, esquire, called in, and examined.

You are aware that the object of this committee is to ascertain, as far as practicable, how far the operation of carriages propelled by steam upon public roads is more or less injurious than the operation of carriages drawn by horses? I have never had any experience of steam carriages upon roads, and therefore I cannot say experimentally what effect they will produce, but if there is no projection upon the surface of the wheel, and they are not suffered to drag upon the road, it does not appear to me that any injury can arise more, but rather less than by common carriages.

Do you consider that, supposing the weight of a steam carriage were equal to that of a carriage drawn by horses, that is two tons each, the injury done to the road by horses or by the carriage would be the greatest? I should expect that by the horses.

In a much greater degree, do you conceive? I cannot exactly say the proportion, but I should think the greatest degree of injury arises from the horses' feet.

What is the nature of the injury done to roads by the travelling of carriages and horses? By the horses chiefly, by tearing up the surface with their shoes. I do not consider that the pressure of the wheels upon a good made road is nearly so injurious to the road as the tearing up of the road by the horses' feet.

Supposing that the operations of a steam carriage were so perfect that there should be no sliding of the wheels, and that such steam carriage were of four tons weight, and also that the joint weight of a coach and horses were four tons, travelling at equal velocity and with equal breadth of tire, which do you think would do the least injury to the road? I should think that the steam carriage would do the least injury, but that is not from experience of steam carriages, but only from my general information, always taking for granted that there is no projection outside the wheel.

If, under those circumstances, the breadth of the tire of the carriage drawn by horses were two inches and a half, the usual breadth, and the breadth of the tire of the steam coach were four inches, should you then have any doubt which would do the least injury to the road? I have already said if the tires were equal, I conceive the steam carriage would do the least injury, and certainly the chance of injury will be lessened if the tire is made double the breadth.

If the breadth of the tire of the wheels of steam carriages could be extended to six inches, might they not, in many states of the roads, be rather beneficial than injurious? Where the road is properly made, of good materials and well consolidated, the mere pressure of a carriage would not have any effect.

Do you think it would be fair to impose an equal toll, weight for weight, on steam carriages and on carriages drawn by horses? I think it ought not to exceed that.

Do you think that it ought to be equal, as the one carriage you state does not do so much injury as the other? In justice it ought to be diminished, but that is only opinion until it is proved.

Have you paid any attention to the mode of charging toll on steam carriages? I have not.

Mr. *William Alloft Summers*, engineer, called in, and examined.

Are you practically acquainted with the operation of steam carriages on common roads? I am.

Have you ever superintended the building of steam carriages? I have superintended the building of two steam vehicles.

What was the weight of the lightest of those steam carriages? The lightest of the two was about two tons ten cwt.

Do you give that from guess or from actual weighing of the vehicle? From actual weighing of the vehicle.

That was without the charge of fuel and water? Yes; without the charge of fuel and water.

What would that add? The quantity of water we carried with that vehicle was five cwt., that carried us about eight miles, and the quantity of fuel we carried would be about four cwt. generally, that would last nearly double the time the water did: we always carried an extra quantity of fuel to meet any exigencies on the road.

On the mean of the distance that would bring it to about four hundred and a half? Yes.

Then the steam carriage, and the average charge of fuel and water, and the persons to guide it, would weigh about how much? About three tons two cwt.

What is the greatest weight which you have known that carriage to be able to carry exclusive of its own weight and charge? I remember, in one instance, that we had ten persons upon it, and that we travelled with those ten persons at the average rate of about nine miles an hour.

On what road did this vehicle you are speaking of, run? It ran from Cable street, Wellclose square, to within two miles and a half of Basingstoke; (it was only an experimental journey—the same vehicle had run in various directions, about the streets and outskirts of London before;) that was the furthest distance we ran with it.

Is it running at the present time? No.

Why was it given up? When we arrived within about two miles and a half of Basingstoke, the crank shaft broke, and we were obliged to put it into a barge, and send it back to London.

Is this a carriage of which the committee have had any information? No; the committee have had no previous information respecting this carriage.

Is this on the same principle as that described by Mr. Ogle? No it is not on the same principle.

Have you a drawing of this carriage? I have not; but I can explain the principle pretty clearly.

Have you abandoned the principle upon which this carriage was formed? Entirely; except that the boiler, with which it was furnished when we ran down to Basingstoke, was the same with which we travelled in the vehicle, of which Mr. Ogle has given a description.

When you were travelling with those ten persons, did you try to increase the speed? Yes.

You were not able to do it? We were not; because the size of our engines would not consume the quantity of steam generated by the boiler, and we were not able to go any faster, the engines not being calculated for taking a sufficient quantity of steam to produce greater speed.

What was the size of the cylinder with which you worked? We had

three cylinders, each four inches diameter, and the stroke of the piston twelve inches in each.

In the present carriages which you run on the Southampton road, what is the size of the cylinders? Seven inches and a half diameter each, and the stroke of each piston eighteen inches.

Do you apply your power immediately from the piston to the crank? Through the medium of a connecting rod only.

You have witnessed the operation of Mr. Ogle's carriage on the Southampton road? I have always been with it.

He has stated that the weight of that is about three tons? It is about three tons.

What is the greatest weight by actual experiments, exclusive of its own weight, that you have seen that carriage draw? We never weighed the present carriage; but I remember nineteen persons being at one time on the vehicle.

To what distance did you carry the whole of those nineteen persons? We carried those nineteen persons a distance of about three miles and a half.

Was that on a level road, or on a road with hills? We ascended two very considerable hills in the distance; it was in the New Forest.

At what average speed did you travel with those nineteen persons? We travelled at the average speed of nearly ten miles an hour.

What was the utmost speed with which you travelled? We ascended one of the hills at the rate of more than fifteen miles an hour.

What do you suppose to be the inclination of that hill, and what the length? I should think the inclination of that hill would not be less than one in twelve, and the length of it from half to three quarters of a mile: it is one of the steepest hills in the New Forest.

If you are able to drive up one of the steepest hills at the rate of fifteen miles, how is it that you give your average speed at less than ten? The reason we travelled with greater speed up the hill is, that the fire was in better order on ascending the hill than whilst travelling on the level road, and caused a greater generation of steam.

You have stated that you went up at the rate of fifteen miles an hour—how did you make that calculation? By counting the number of revolutions made by the hind wheels.

Are you quite sure there was no loss from slipping during that period? I am quite sure there was no loss.

Having ascended the most difficult part at the rate of fifteen miles per hour, and placing your mean power at so low as ten miles per hour, and stating the reason of the mean being so low that the fire was in better order at one period than another; does it proceed from any defect in your fire place which renders it difficult to keep the fire always at a certain power? At that time we had not the means of stoking or putting fuel on the fire through the centre of the boiler; the consequence of which was, that we were obliged to put a greater quantity of fuel on the fire than we otherwise should have been, which caused the fire to be a considerable time before it burnt through the fresh fuel; but having lately made a trifling improvement in our boiler, we now average, with the present vehicle, fifteen miles per hour.

Were you travelling for hire on that road? We have never travelled for hire yet, but merely on experimental journies.

You have never made the experiment of weighing your carriage to ascer-

tain at what rate you can travel with any particular weight? We never made the experiment, except by carrying persons.

Do you find it easy to increase the velocity with any certain weight? That depends on a great many circumstances; the state of the roads has very great influence on that; but our power is capable of being increased to almost any extent.

As an engineer, what should you say would be the greatest weight which can be carried by a carriage weighing three tons at the rate of ten miles an hour? I have no doubt it would be able to carry three tons at the rate of ten miles an hour besides itself; and after the improvements I have in view are completed, I have no doubt that much greater weights may be carried at that rate.

Have you ever tried it? We have never tried it; but I ground my opinion on having seen the steam blowing off at both safety-valves, with tremendous violence, during the time we were travelling at the rate of upwards of thirty miles an hour.

What distance have you ever continued travelling at the rate of thirty miles an hour? We have continued travelling at the rate of thirty miles an hour, four hours and a half very frequently, and could have continued to have gone longer, had we not required a fresh supply of water, our tank not being quite large enough.

How could you continue to travel at the rate of thirty miles an hour, when you have already given so low a mean of the average of travelling on account of your fire place? Because it depends entirely on the quality of the fire: we have never found any difficulty in travelling over the worst and most hilly roads since our last improvement in the furnace, when the fire is in good order.

Have you watched the operation of your propelling wheels on the road? Continually.

Have you ever seen the operation of a drag on a common coach going down hill? Very frequently.

What is the effect produced on a road which is nearly dry? The effect produced on a very hard road, when nearly dry, is very trifling, but on a soft or gravelly road it does great injury.

Does not it produce a glossy appearance on the rut? Always.

Is that same effect produced by your carriage in going down a hill? No, certainly not; because our wheels in going down hill are always revolving.

By what operation do you decrease the velocity of the carriage going down the hill so as to check the inclination of itself to run down the hill, and yet keep it under control? On arriving at the brow of the hill, we throttle or wiredraw the steam in order to check the velocity of the engines, and if we find that the hill is so steep that the carriage would run faster than we wish, we have two drags attached to the hind wheels, and with the foot we press on one drag or on both, as it may be required, and by that means regulate the velocity of the carriage.

Does not that stop the motion of the wheel? No, it does not prevent the wheel revolving.

How is the drag applied? It is a kind of iron band or strap which goes round a portion of the tire or the wheel, and our power of breaking is multiplied by levers to a very great extent.

You have stated that the utmost weight your carriage would carry, at the rate of ten miles an hour, was three tons; do you think you would be able to

carry a much greater weight at the rate of five miles an hour only? Certainly we should.

To what extent should you increase your power of carrying? I cannot answer that from experience.

At what period of slow motion do you think that the increased expense of fuel would be greater than the use of horses in draft? I have not ascertained that from experiment; but I think steam will supersede horses in drawing carriages, even at low velocities.

How often do you find it necessary to clean your boiler? We have never found it necessary to clean it yet: it has been in operation more than twelve months.

Do you conceive that is owing to the peculiar quality of the water, or that, under any circumstances, that would happen? We have had water of every description.

Is there no incrustation upon it? Not the slightest.

Supposing there were incrustation upon it, would it be difficult to clean it, and would that require an engineer? It would merely require a common laborer to clean the boiler, which might be done by removing some plugs that communicate with each of the cylinders of which the boiler is composed, and, when required, may be done with a scraper or wire brush.

What becomes of the carbonate of lime and the sulphate of lime, and so on, which are in solution in different waters? Every time after we have arrived at our journey's end, we open a cock communicating with the bottom of the boiler; perhaps we do not give the matter time enough to rest: it is all blown out at the pressure of 240 lbs. on the square inch.

Have you ever had your boilers rent? No, we have never had an instance in which the boiler has given way in any part of it; and, in several instances, we have had it red hot.

Of what material is it formed? Of the best charcoal iron.

Have you ever tried it by pressure? I proved the boiler before it was put into the steam carriage at 364 lbs. on the square inch; it will support 740 lbs. on the square inch,

At what pressure do you work? We usually work it on the road at a pressure between 240 and 260, finding that pressure more economical than any other.

What surface of iron is exposed to the fire and heated air? Two hundred and fort-five superficial feet: the weight of the boiler is eight cwt. two quarters.

What is the thickness of the iron? About one-tenth of an inch; thin boilers last longer in proportion than thick ones, because the heat sooner passes through it into the water, and has not time to act upon the iron.

For what period do you conceive that it is calculated to last? From having had twelve months' experience, I should say it would last very well two years and a half.

During what portion of the twelve month was the engine in actual operation? It has not been in constant operation every day; but we have been in the babit of going out four days out of six, and working from eight in the morning till seven or eight o'clock at night; the boiler is not at all injured, it is in the same state in which it was when first put into the vehicle; neither have we had any accident with the machinery, contrary to the opinion of almost every engineer who saw the vehicle before it left London. The vibration or jar being much less on common roads than on a railrway, and the whole of our machinery being suspended on springs; the engines work as smoothly as if they were fixed on the firmest foundation.

Where are the passengers placed, in reference to the boiler? They are placed in front, and in the middle of the vehicle, and the boiler is entirely behind the body of the carriage and passengers.

You are frequently in the habit of passing horses? Yes.

Do you find that they are frightened? I have occasionally observed them shy, as they sometimes do at a wheelbarrow; but we never had any accident from horses being alarmed.

Do you find it less now than at the commencement of you experiment? Certainly.

Is there a peculiar noise attends the motion of your engine? The noise is not as great as in a vehicle drawn by horses.

Is there any peculiar noise from the escape of your steam? I cannot say that there is no noise at all; there is a noise, but it is so trifling that the rattling of the wheels on the road entirely drown it.

Is there continually steam being let off from the safety-valves? Almost continually.

Does that produce any disagreeable effect to the passengers? None whatever: all the waste steam is blown into the furnace, which entirely prevents any noise that can be heard on the road.

It has been stated to the committee, that, in some steam carriages, actually in operation, there is a very peculiar noise from the escape of the steam, from whence does that proceed? It proceeds in one carriage, which I have seen running along the roads, from the steam being blown in at the bottom part of the chimney of the furnace, at a distance very near to the open air.

That may be obviated by a different form of chimney—may it not? No doubt it may.

You are aware that that principle is one of the most important principles which has been introduced into the working by steam? I am quite aware, that, on the Liverpool and Manchester railway, that is the principle they have adopted with some success. We have produced the same effect by another, and I think better means.

Will you state by what means you produce that effect? Instead of blowing our waste steam into the chimney, in order to produce a draught, we have a fan or blowing machine, which is driven by the engines when in operation, and this gives us intensity of heat in the furnace. The waste steam from our engines goes into a double casing round the furnace; we admit a small portion underneath the firebars of the grate, and the remainder is allowed to expand itselt into the double casing, after which it comes over the top of the fire, and escapes in the form of invisible vapor.

Then, in fact, you arrive at the same result, but with this difference, that you increase the draught of the fire by using a certain quantity of the power of your engine, whilst those who introduce the steam into the chimney increase the draught by a power which you throw away? We have tried it in both ways, but we find this the most advantageous, because in those carriages in which the steam is driven into the chimney to produce a draught, the aperture is so much diminished in order to produce velocity of current and corresponding increase of draught, that the waste steam is choaked in escaping from the engines, and produces a greater loss of power than by working the fan.

From your experience in steam carriages, do you conceive that it will be necessary to make any alteration of the present roads, such as paving them for the purpose of this mode of conveyance? No, certainly not; we have

found that our vehicles will travel over every kind of road with great velocity, and up the steepest hills. From observation which I have made very minutely on the operations of the vehicle, my decided opinion is, that if the common roads were put into a tolerably good state of repair, we should be able to carry all the goods which a railway would be able to carry, and at much less expense, taking into consideration the original expense of the railway, and its continued wear and tear. I believe I have, from a correct source of information, that every yard of railway loses on an average about four ounces per year in weight when it is in full operation. This loss arises from oxydation, and the action of the great numbers of wheels of the carriages that pass over it.

Have you travelled over pavements? Very frequently.

Did you find that your carriage travelled with greater case over them? With much greater case.

Supposing you had a pavement to run on, what increase of power should you gain by running on that rather than on a common Macadamized road? We find that when we are travelling on a rough bad pavement, we do not consume more than one-fourth of the steam we do on a gravelly soft road.

You conceive you increase your power ¾ on a paved road? Yes.

What steepness of hill have you ever ascended? One foot in six; I measured it myself; that is, the hill at Shirley.

Were there any symptoms of the wheel slipping in that case? Not the slightest: we had both the wheels in gear at the time we ascended it.

At what velocity did you ascend it? At a velocity of nearly five miles an hour.

What weight had you? We had fourteen or fifteen persons on the carriage.

Did you find any difficulty in working? Our engines worked with perfect freedom.

What distance did you travel on that ascent? The hill is about 200 yards long.

You are now improving the form of the carriage—are you not? Our present operations are in improving the form of our vehicle, and the arrangement of the different parts of the machinery.

For what number of passengers will your present carriage be calculated? Eight inside and sixteen outside passengers.

How many wheels have you? Our present vehicle is on three wheels; our proposed carriages will be on four wheels.

In what space can you turn on a road? We have frequently turned entirely round on the London road leading from Southampton, in the space in which a post chaise can turn, or rather less.

Supposing you were travelling at the rate of ten miles an hour on a level road, in what number of feet do you suppose you should be able to stop your carriage entirely? We should be able to stop the vehicle in the space of twelve feet. I have ascertained this from experiment: when we were descending Staine's bridge, which is very steep, one of the crowd fell down in front of the vehicle, very near the vehicle; we immediately reversed the action of the engines, and the man escaped without any injury.

When you state that you can stop in twelve feet, is that by reversing the action of the engines? No; by merely shutting off the communication between the boiler and the engine.

But supposing you were in such situation that it would be requisite to stop in a much shorter distance, could you do it instantaneously by reversing the engine? We could certainly stop in the space of three feet by reversing

the engines; but it would not be prudent to do so in less, as it might endanger the lives of the persons on the vehicle by their being pitched or thrown forward.

Have you turned your attention to the question by what mode tolls would be most fairly charged on such carriages? I have not turned my attention much to that subject.

What is the horse power of your engine, according to the common modes of calculation by engineers? About twenty horse power.

On the Liverpool and Prescot road, the toll for steam carriages is as follows: for every carriage not drawn by horses, but propelled or moved by machinery, any sum not exceeding the sum of *1s. 6d.* for each horse power: would you be able to run your coach, subject to a toll so high as that? We certainly should not be able to run it to any advantage.

What advantage in point of expense do you anticipate to the public from the use of steam in propelling carriages over that by horses? I have no doubt that when they arrive at tolerably practical state of perfection, passengers will be carried the same distance which they are carried now by horses, at the same velocity, for one half of the expense; it may be even at less than that in future.

What mode should you suggest as the fairest for placing tolls on those carriages, by passengers, by the wheels, by the horse power, or by the weight? I should certainly suggest that the tolls should be levied by the number of passengers the vehicle carries, provided the breadth of the tires of the wheels be increased in proportion. As to vehicles for carrying merchandise, I think the tolls should be in proportion to the weight which such vehicles are capable of carrying—the velocity of the vehicle travelling on the roads not materially affecting the state of them.

Many turnpike acts having passed this session, which place tolls on steam carriages, how would Parliament be able to adopt one principle of placing toll on the passengers? The proprietors of steam vehicles will always carry as many passengers as they can, and the greatest number of passengers that they are able to carry should be the standard at which the tolls should be levied.

Supposing that, on two roads, the toll on a coach calculated to carry eighteen persons, was *2s.* and on the other *3s.* how would you propose that any scale should be adopted by which a toll could be introduced applicable to both those roads? My opinion is that the toll on steam carriages ought not to exceed one half of the toll paid by other vehicles drawn by horses, because they do not injure the roads more than in that proportion, probably not so much, the tires of the wheel having been increased in proportion.

Your new carriage will be calculated for twenty-four persons—the average of coaches carry eighteen at their utmost—how would you proportion the tolls on your carriage and on carriages drawn by horses? My opinion is, that it would be but justice that the steam vehicle in such case should not pay even more than one-half that which is paid by other vehicles carrying the same number of passengers; therefore, supposing the average of coaches carried sixteen passengers, and that the toll charged upon them was *2s.*, the toll paid by the steam vehicle, carrying twenty-four passengers, should be 1*s.* 4*d.*

What do you think ought to be the breadth of the tire of a steam carriage calculated to convey sixteen passengers? Three inches.

What do you think should be the breadth of the tire of a carriage calcu-

lated to convey twenty-four passengers? Not less than four inches; probably it may be found advantageous to make the tire wider than that in practice; I think it probably will.

Do you think that steam carriages should be licensed to carry a certain number according to their power? I think they should.

What do you mean by their power? It will be to the advantage of every steam coach proprietor to carry as many passengers as he can, giving each passenger sufficient accommodation, and he should have a license for that number and no more: each of the passengers should have the same quantity of space allowed them as they have in the present vehicles drawn by horses; it is my opinion it should be the comfort of the passengers which should be consulted.

Should you have no reference in the license to the power of the engine? I think not; because the danger does not increase as the power of the engine increases.

How would you suggest that an equivalent duty should be placed on steam carriages, so as not to give them an unfair advantage over common coaches? I am not able to give any opinion upon that subject.

Can you give any reason why the same amount of duty should not be charged on steam carriages as is charged upon the present stage coaches? I cannot give any reason, except that I think it would be extremely improper to place such duties on steam vehicles, in their present infant state, as to crush so important an invention.

Mr. *Joseph Gibbs*, again called in, and examined.

Have you any observations to make, in addition to your evidence given last Wednesday? With a view of giving my opinion upon the best method of collecting tolls from steam carriages, I will commence by stating that steam carriages can be constructed upon three several principles; my object being to show this honorable committee the difficulty in collecting tolls from steam carriages, except by the number of wheels, without stopping the progress of that improvement in which they stand so much in need. Steam carriages can be constructed as follows: first, steam carriages which propel themselves, and carry the supply of water and fuel, likewise passengers and goods; second, steam carriages which propel themselves, and carry the supply of water and fuel, but draw the load after them in a separate carriage or carriages; third, steam carriages which propel themselves, and partly carry passengers, goods, fuel and water, and draw the rest in a separate carriage or carriages after them. This will show the great difficulty of levying a toll upon the weight of steam carriages; as, for instance, 600 lbs. of water and 100 lbs. of coke are requisite per hour on an even road, with a steam carriage as now constructed; but upon a road, abounding with hills, 1,000 lbs. of water and 160 lbs. of coke will be required. Now if the weight is taken when the water and fuel are one-half diminished, say on the average 400 lbs. of water and 65 lbs. of coke, and the toll is levied upon the weight of the steam carriage, the carriages (being drawn) paying as ordinary carriages, the weight of water and coke can be transmitted to those carriages which paying, not by weight but by the number of wheels, will of course receive an augmentation of from five to six hundred pounds additional weight. Likewise the danger from explosion will be increased if tolls are collected upon the weight of steam carriages, inasmuch as by loading the safety-valve to double the pressure, a carriage can be made to draw double the weight

with only an alteration in the fire place, and an increase of water, air and fuel; a diminution of weight will likewise take place to a considerable amount in the boilers and engines, although it is more essential an increase of strength should take place rather than any diminution. I can state a case in point. I have a steam carriage now constructed, from which I could abstract 900 lbs. of iron without making it too weak to travel even on rough roads, but I should not be induced to do so except as a matter of economy in case the tolls are levied upon the weight, and at too high a rate. The steam carriage as used upon common roads, being an invention of recent date, sufficient has not been done with them for practical men to decide what arrangements of machinery are best for their construction. It may be found hereafter that it is proper to place the engine in one carriage and the boiler in another, and blowing apparatus in another, all carrying other weights, so that three distinct carriages (although they each carry only a part of a steam engine with them,) yet if so arranged, and tolls are collected by the weight of the steam engine, the whole of these carriages would be liable to pay toll by weight. I think that, in carrying heavy goods, it is more than probable the steam engine will be on a separate carriage, and the power transmitted to the hind axle of the carriage containing the goods, by means of a flexible bolt or intermediate wheels, in order to obtain a slow motion of the carriage, the speed of the engines being the same; but does not this connect them, so that they may be considered as one carriage, and liable to pay by weight? As it is probable that steam carriages or locomotive engines will be used for ploughing, or to draw the plough to it, the engine remaining during that time in its location, and only moving when the plough has completed its furrow, yet, in going and returning to the field, it may travel upon a turnpike road, and be subject to the toll of a steam carriage; an engine of this description will be very heavy, and, unless a provision is made, the farmer would be obliged to attach horses to it to prevent its being considered a locomotive engine. It appears to me that the only method of collecting tolls is by payment (under proper regulation) on the number of wheels employed, and not on the weight of any part of the train, for if one part pays by weight and the other upon the number of wheels, the weight can be removed to a dangerous extent from the part paying by weight, and placed to an injurious extent upon the part paying by the number of wheels. I can well appreciate the difficulty the committee must have to contend with in coming to a just decision as to the best method of levying tolls. I have been a number of years constantly having new inventions under my consideration, as well as being the inventor of several patent inventions which are now in full operation: therefore, without presumption, I feel myself qualified to give an opinion. I have constantly observed that all new invented machines entirely change shape, dimensions, weight and general arrangement of parts as they proximate to perfection, so that the perfect machine could not be recognized, by persons unacquainted with the subject, as being intended for the same purpose as the original machines, yet, during all these successive alterations, the principle of the machinery remained unchanged. I make these observations to show the difficulty of anticipating the ultimate power and dimensions of locomotive carriages.

Will you exemplify your proposition as to the payment of tolls, giving 2 *s.* as the amount of the tolls for a carriage drawn by horses; what amount of tolls should be charged on the two following steam carriages, the one carriage to carry passengers on itself, and to weigh four tons; and suppos-

ing in the second, the engine part of the carriage to be separate, the engine carriage and the carriage drawn weighing together four tons, should a higher amount of toll be chargeable on the one steam carriage than the other? I think not.

Yet the one has four wheels, and the other has eight wheels? My opinion is, that it ought to pay the same tolls it does now, supposing they are of equal weight, the diminution of the horses being taken into account.

Then your proposition would be resolvable into charging tolls by weight? Of course; I contemplate that a regulation will take place, that only a certain weight shall be placed upon the wheels, and the width of the wheels will come under a regulation.

Then it becomes absolutely a toll on weight? Not exactly so; I am only stating the limits I think they ought to carry.

In the case stated on the one steam carriage carrying the passengers with the engine, and the second the engine being placed in a separate carriage from that containing the passengers, both carriages being of equal weight, that of four tons; but in the one case there being eight wheels, and in the other only four, would you charge a different amount of toll on those two carriages? I would charge in proportion to the weight carried. In stating this, I conceive that there should be a maximum weight which steam carriages ought not to exceed.

What should you suggest as the standard of weight? I have not turned my attention to that part of the subject, but I will do so if it is wished.

Are you aware what the average weight carried in vans is? I have made inquiry from van proprietors, and find that they frequently carry six tons, including the weight of the van, but the average weight is about four tons, and the width of their wheels is from $2\frac{1}{8}$ inches to $2\frac{1}{2}$ inches.

Do you anticipate that steam will be applied shortly for the purpose of conveying goods in vans? I believe it will; I contemplate the putting some vans on the road to be worked by steam.

Will such carriages be on four wheels, or on any greater number? I think it probable that they will be on a greater number than four wheels—from six to eight wheels.

What do you conceive to be the maximum weight that ought to be placed on a wheel of three inches width? One ton and a half ought to be the utmost limit.

Jovis, 25° *die Augusti*, 1831.

Mr. *James Stone*, called in, and examined.

What are you? An engineer.

Have you had the superintendence of Sir Charles Dance's steam carriage? Yes, I have.

On what road does it run, and how long has it ran on that road? It was running regularly from the 21st of February to the 22d of June, inclusive.

During that period has any accident occurred? Yes, by the breaking of the axletree.

Mention the nature of the accident? We supposed it broke in consequence of an unusual quantity of stones laid down upon that part of the road that was always the most difficult to pass over: but no accident as to the

bursting of the boiler, or any other thing took place, that occasioned any unpleasantness, or any thing like a serious accident as to injuring any persons. We had several little stoppages from defective tubes, of which the boiler is constructed; but nothing accrued from that, except merely stopping the progress of the carriage.

Was the carriage able to work with the axletree broken across? It broke about a mile and a half from Cheltenham, and it came back all the way to Gloucester, notwithstanding the axletree being broken: one of the engines was able to work during that time, and, of course, having only one engine, when it came to a hill, the men were obliged to assist it over the centre, as there was no momentum.

Can you state, accurately, the weight of the carriage? I cannot.

As far as you have observed, is the injury done to the roads by the passing of the carriage, greater or less than that by a carriage drawn by horses? I think, taking the horses into the account, the injury must be much less; the tire of the wheels three and a half inches wide, whereas many of the tage coaches are as heavy as the steam carriage, and with narrower wheels; and I think it is only fair to take the weight of the horses into the account, which I have found to be from eight to ten hundred weight each horse; consequently, four horses would weigh from a ton and a half to two tons.

You are answering now from theory—you were directed to answer from observation? From observation, I do not think that the steam carriages injure the road so much from the wheels being wider.

How frequently do you clean the tubes of the boiler? It would be necessary to clean them once a month; I should recommend that, but if they were actually cleaned once in three months they would not give away: it depends upon the quality of the water made use of.

Is there great facility in cleaning them? Very great; it is merely removing oppsite the end of the orifice of the tube the screw-bolt; it is only to withdraw the screw-bolt and introduce the cleaning rod. We are in the habit of blowing out the tubes every two or three days to cleanse them.

What is the greatest number of passengers you have taken on that carriage? Thirty-six.

Thirty-six passengers and their luggage? Yes, but being a short stage, there is never much luggage.

What do you suppose is the greatest weight you could draw by that carriage, at the rate of ten miles an hour? From forty to fifty hundred weight; it is found to be drawn much easier by dividing the weight into two carriages than taking it in one only.

Do you work, on an average, at half your utmost power of working with safety to the engine? I should think we did.

Full half? Yes.

Do you think more than that? It depends so much upon the state of the fire.

The question was, do you work, on an average, at half your full power? Yes, I should think we did. The greatest weight we ever drew on the common road, at a rate of from five to six miles an hour, was eleven tons.

Is that merely by guess, or did you actually weigh? By weight; we made the experiment on the Bristol road.

What should you suppose to be the weight of the drawing carriage? The weight of that was upwards of two tons.

Then it drew five times its own weight? Yes, it did; the eleven tons I

have stated, included the weight of the drawing carriage; and I did no consider that the maximum power, at all.

Did you ever try it at a less velocity? No, because, in applying the greatest power, we confine both the wheels to the engine.

Did you draw the nine tons with only the power of one wheel? Yes.

Are you able, from the two circumstances you have mentioned, to say, that, at three miles an hour, you could draw considerably more weight? Yes, I have no doubt of it whatever.

On what breadth of tire was that weight drawn? I think the tire was five inches of the propelling carriage.

For what distance did you continue to draw that nine tons? A mile and a quarter.

Did the road vary in its inclination? Yes, a little; the greatest elevation could not be more than one in twenty-five.

Did you ascend an inclination of one in twenty-five with that weight? Yes, we did.

For what distance? From twenty to thirty yards.

And, on the average of the mile and a half, and it an ascending or a descending road? It was both; there were little undulations in the road.

Can you measure accurately the power you are employing at any particular time—have you any gauge? No, we have never applied one; I have conceived one, and am going to apply it.

The barometer tube? Yes, that is the one. I think it right to state, that the wheels were taken off that measured five feet diameter, and others were substituted, measuring only three feet diameter.

Do you wish to have it inferred from that, that you employed, in both cases, the same amount of power? There must have been a little more power with wheels of three feet diameter.

Do you think you exerted your utmost power when you were drawing nine tons? No, and for the reasons stated, that there was only one wheel affixed to the engine.

May you not exert your utmost power upon one wheel, taking into consideration that the strain is greater? No, the wheel would slip round.

Was the surface of the road on which you tried that heavy weight broken up, or in any way rough, to give a greater amount of friction? No, it was a good hard road.

What proportionate charge do you make for conveying passengers between Cheltenham and Gloucester? One shilling.

What do the coaches charge? Half a crown the four-horse coaches, and two horse coaches *2s.*

Travelling at the same speed, do you think you could charge in the same proportion? Yes.

There would be a saving to the public of more than one-half? Yes.

Have you taken many passengers? Yes, a great number; from February to June, between three and four thousand passengers. I have a book containing an account of the number of minutes that each journey took.

The committee have received a letter from the surveyor of the Gloucester and Cheltenham road, stating that there is a very great noise proceeding from this carriage? I have not heard that observation generally; there is a little noise, but not much.

With red hot burning coals falling on the road continually, or whenever the fire was moved? That has taken place when the ash pit has been burnt

out, but that is not necessary. The carrriage I have recently fitted up will not be subject to that.

You are of course aware that the letting coals drop is desirable to be obviated? Yes, and that I have guarded against.

He also states few animals will pass it without being frightened; and often the traveller was obliged to take his horses into the fields adjoining the road; and very many who did not use that precaution had been placed in the most perilous situations; and that a gentleman's carriage in the neighborhood, was overturned from the horses taking fright at it? Yes, I have understood that; but that carriage has been overturned once or twice owing to the carelessness of the driver. I have seen the gentleman, and he did not think any thing of the accident, the coach turned round, and the coachman jumped off, but I never saw any thing bordering upon an accident during the time I was with it.

He states that persons have completely deserted that road? I have never known but one individual that has been against it at Gloucester; but I have seen horses take fright at a stage coach and not at our carriage. In one instance, going out of Gloucester, we were just behind the stage coach, and a horse in a chaise coming past took fright at the stage coach, and when he came up to us he took no notice of us, and therefore, I am fully persuaded, that horses do not take more fright at us than at a loaded stage coach, from the observations I have made upon a number of experiments.

Were there 14 inches of stone laid on the road at the time the accident happened of the breaking the axletree? Yes, it was; when the stones were levelled, they measured seven inches, but, at that time, they were merely laid across the road, so that the carriage could not pass them without going through them.

Do you know that the passengers on the common stage coach got out and helped the coach along? No, I do not know it: I only heard it, I do not know it.

Mr. *James M'Adam*, called in, and examined.

Are you surveyor of the Holyhead line of road? As far as St. Alban's.

Have you the superintendence of any other portion of it? Of no other portion of it.

Have you had considerable experience in road-making, and superintending roads? Yes, for the last fourteen years.

Have you made any experiments, or are you able to give any information to the committee, as to the comparative wear of roads, or injury to roads by carriages and horses passing? I have generally found that horses' feet do very great injury to the surface of a well-made road; and I am of opinion that a carriage, with properly constructed wheels, does less injury to a road than the horses drawing.

Would you explain what the operation of the injury done to the road is by travelling on it; is it the wear of the road, or the displacement of the materials? Both take place; the wheels, to a certain degree, wear out the material, but, upon a road properly constructed, and that has become consolidated, and the surface smooth, that wear is very small and gradual; the injury to the road from the horses' feet, more especially upon gravel and flint roads, arises, particularly in dry weather, from the knocking up and displacing the materials upon the surface, and each succeeding journey adds to the evil, and were it not for the effect of the wheels following the horses

in mitigation of that evil, we should have the flint and gravel roads all loose throughout the whole summer.

But the wheels of the carriage do not actually follow in the track of the horses? But in roads of much thoroughfare, especially near the Metropolis, other carriages do.

On the Metropolis roads, have you made any new regulations as to the mode of charging tolls by weight or otherwise? In the last act passed for the Metropolis roads, the toll was put upon the horse drawing, and a regulation as to the formation and breadth of the wheels expressly enacted, by which all wheels were required to be not convex, but a perfectly flat surface, with no projecting nails; but, by the powers granted to the commissioners in that act, that perfectly flat surface was mitigated to a surface not exceeding a quarter of an inch from the flat surface; to meet the practical effect arising from the wear of the wheels upon the road; and to prevent litigation at the several gates, by applying a guage, a toll of *3d.* per horse for each seven miles is payable upon a six-inch wheel so constructed; a quarter more upon a wheel so constructed of four inches and a half in breadth, and a half more upon a wheel less than four inches and a half. Those additions do not apply to stage coaches or carriages with springs. The toll upon all horses drawing carriages and coaches with springs is *3d.* a horse for seven miles, whatever may be the breadth of the tire.

You have had no reference to the weight of the carriage drawn in your rate of the tolls? There is no reference to the weight drawn in any wagon or such like carriage, provided the wheel is of the construction required by the act, and the result of some years' experience proves that no injury whatever is sustained upon a well-made road, from any weight practically carried in wagons, or such like carriages, with wheels as described.

You do not mean that the committee should infer weight is of no consequence, but that the power of the horse will be your guard against an overweight being drawn? Yes; the toil being laid per horse, I consider that the penalty in the shape of toll per horse, more than compensates for the injury done by the weight. Before those regulations took place, the roads in truth sustained an equal pressure, from the well known fact that the weighing engines were universally compounded for by all the carriers, and that the roads, after these regulations, had no greater but even less weights to sustain than before that took place, and it was observing that fact, which induced the commissioners of the Metropolis roads to do away with all the weighing engines.

Do you know whether the Holyhead road commissioners are trying to do away with the necessity of weighing engines? Upon the trusts, on that line of which I am surveyor, the trustees have done away with all the weighing engines, and the happy result of compelling the wagons to set out and arrive upon the Metropolis roads with properly constructed wheels, has had the effect of enabling the trustees upon all the roads within a circle of fifty to eighty miles, to dispense with the weighing engines; also, because if the wagons set out and arrive in the Metropolis district with a properly constructed wheel, it was not worth their while to alter it, but to travel throughout to Cambridge, Newmarket, &c. with the same wheel; and the benefit of the metropolis wheel has extended itself in consequence.

Then supposing a broad wheel wagon with dished wheels was to pass through your turnpike, what rate would be charged? It would be charged the highest rate of a narrow wheeled wagon.

Have you heard any complaints from the wagon masters of the regulation of the form of the wheel? On the contrary, a few days since, we had a petition most numerously signed by the wagon masters from Norwich, Cambridge, Newmarket, &c., requesting the trustees of the Wadesmill road to dispense with use of their weighing engine, they having found by experience that the wheels required by the Metropolis commissioners, were not only best for the road, but the most advantageous for themselves to use, and in consequence of that application, on Friday last, the only remaining engine on the roads of which I am surveyor, was ordered to be abandoned.

Can you state the weights of a loaded stage coach, and a loaded wagon, and a loaded van, on the average? I should state a stage coach loaded, at from two and a half to three tons; a wagon from five tons to seven and a half.

Does that include the weight of the wagon? Eight tons would; I should think the weight of the vans about four or five tons.

Have you observed the operation of wheels when they are dragged? Yes; they are injurious upon roads newly coated certainly, but upon an old road, I mean a road that has become consolidated upon the surface, the injury, with proper skid pans is but small, and confined of course to one side of the surface of the hill.

Do you think the efficacy of your toll in protecting the road is equally applicable to a heavy van as a loaded coach? I think that the toll per horse will always be a sufficient guard for the weights drawn, the van being on springs does infinitely less injury in proportion than such a weight without them.

But if the injury to the road proceeds from the weight the horses have to draw, the same rate of toll would not be applicable to a carriage of two tons and one of six tons, both being drawn by four horses? Certainly not; but that is a supposition hardly fair to be taken, because we conclude that the additional weight requires additional horses.

But in practice the vans pass all through the country with only four horses, and the coaches equally with four horses? That is true; the coaches go at a much more rapid pace.

Do you think that the velocity with which a coach goes, has any thing to do with the wear of the road, or is it not actually less injurious in proportion to its velocity? In some instances, where any blow takes place, the speed does more injury to the road by crushing the materials.

You did not contemplate the general use of vans when that act was drawn up? No; not that they would come into such general use.

What proportion of the injury to the road do you think takes place from the changes of the atmosphere; frost and wet, has it any material effect? Yes, decidedly, in chalk soils in particular; at Royston, and through that country, a great and serious injury takes place upon the breaking up of all frosts, nor can we, by any care or attention or strength of surface of the road, prevent that taking place; it comes in a very eccentric manner, and breaks up one year at one part of the road, and another at another, occasioned in a great measure by the standing of the water in the sub-soil; and I suppose also, by the way in which the wind is at the time it freezes. It is the modern practice of road making to abstain from all general repair of the roads from the middle of April until the middle of October; during that period, the only repairs that ought to take place are partial coatings, necessary from accidental circumstances. As soon after the middle of October

as possible the general coating takes place in pieces of the road at a time so as to interefere and interrupt as little as possible with general travelling, and we endeavor, by the month of February, to have the whole of the coatings put on; in no instance above a sixth part at a time.

On your line, the committee find that the course of horizontal traction varies from 42 to 140; with these remarks, in the case of 42 "granite surface of many years standing," and the 140 "smooth surface road made of broken granite;" can you explain why such a difference should take place, both being smooth surfaces? I am quite unable to account for it; no coatings of dirt upon a granite road ought to have produced so great a difference.

Have you witnessed the operation of a carriage propelled by steam on the public roads? I have observed it; but in a small degree.

Who was the proprietor of the carriage you noticed? I think it was Mr. Gurney's; I accidentally saw it.

Then you only saw it once? Only once.

What was the state of the roads when you saw it? Tolerably good at the time; I saw it in the Regent's park.

Were they in such a state you could make any observation upon the greater or less injury produced by it than by a common carriage? I cannot say that my attention was directed at that time to that fact; I have not had an opportunity practically of seeing the effect of steam carriages upon roads; there have been none used near us except passing down to Virginia water, &c.; but not being brought into general use, I have not seen sufficiently the effect of their wheels upon roads.

From the experiments you have before stated, what should you recommend should be the breadth of the tire of the wheel of a carriage with four wheels weighing four tons? I consider that a carriage of any description required to carry a great weight, five or eight tons, ought to have a wheel of four inches and a half in breadth, constructed agreeably to the clause in the Metropolis act; and I consider that a carriage with such a wheel, though carrying an excessive weight, would do very little injury to the road.

It has been stated by a previous witness, that a carriage of the weight of two tons propelled by steam, drew after it another carriage weighing nine tons; what should, from your experience, be the breadth of the tire of the wheel of the propelling carriage and the carriage drawn? Looking solely to the welfare of the load, I should prefer a wheel of four inches and a half, flat on the tire, to any other class of wheel that can be made, being of opinion that a greater breadth of wheel cannot at one time touch the surface of a well-formed turnpike road.

Then you would prescribe that breadth as the minimum breadth of wheel for any weight? Yes; I do not think any increase of breadth would be of any service.

Supposing two carriages, one drawn by horses, and the other propelled by steam, the weight of the steam carriage being four tons, and the weight of the carriage drawn by horses being two tons, which would do most injury to the road, provided the breadth of the wheels were the same in both cases? I should prefer, with a proper wheel in both cases, the steam carriage without the horses, because that question can only be answered with reference to the wheel.

Then, in the case given, if the wheels of the steam carriages were four inches and a half, and the wheels of the coach two and a half, which would do the greatest injury? The coach, decidedly, drawn by horses, though only

two tons and a half, infinitely more; because I consider, that of all classes of thoroughfare at present, the stage coach, as usually laden, does us the greatest injury.

Can you suggest any mode by which tolls could be fairly charged on steam carriages in relation to the tolls charged on coaches? The mode adopted in coaches, of taking toll per horse as well as wagons, has been found to answer every purpose, it being, in truth, a penalty upon weight. If greater weight is put upon a wagon, a greater number of horses are necessary to move it, and the parties bring the penalty in the shape of toll in their hands. This cannot be applied to steam carriages, and I am at a loss to recommend to the committee any general mode, unless the diameter of the cylinder or power of the engine could be taken. In the Metropolis act of 1829, there is a toll laid upon steam carriages; any carriage that shall be in any manner drawn by steam or gas, shall pay the toll that would be paid by any carriage drawn by four horses.

If the power of the engine is equal to any number of horses, you only charge the same toll? The same toll.

Then if a steam carriage drew another carriage after it, or two carriages after it, would it be two or three tolls, or one only? Two or three tolls; where a steam carriage conveys passengers by drawing another coach, they would each pay the toll of four horses: this is a matter still in its infancy; in many acts, such as the Lemsford mills act, a toll of half-a-crown was introduced for any carriage drawn or propelled by steam.

Would not this inconvenience arise from the clause you have read in the Metropolis tolls act; it would be a premiumgiven in favor of one description of steam carriage over another, though the injury done to the road might be in favor of the one less taxed, as in the case of a steam carriage carrying 20 passengers, and another steam carriage drawing a carriage containing the same 20 passengers? In that case the toll would certainly be an unjust one, and require revision; it was a point not settled, and it was put in merely to commence the toll, and call the public attention to it. I beg leave to observe, that if these carriages come into general use, they would necessarily require a still greater perfection in the surface of our roads, and also in the levelling of the remaining hills; as good surface and little inclination is to them of the greatest importance.

If that is the case, would it not be necessary to lay considerable rate of toll upon those carriages, for the purpose of affording the means of executing those improvements? It is found, that lowering the hills, and improving the surface of all the roads, is productive invariably of a great increase of thoroughfare; and although lowering the hills might be attended with the first expense, any excitement that would induce the trustees of the roads to keep them in good order, would be at the same time productive of economy, a good road being always the cheapest.

Do you not suppose, if those carriages were in general use, the very action of the wheels upon the roads would prevent the necessity of such frequent repairs as are required at present? I should think that the absence of the horses' feet in a great degree upon the roads, would be a very considerable saving; and I have already stated, that these carriages, with properly constructed wheels, would be the class of carriages that would do the least injury to the roads.

What is the greatest speed you have known a carriage drawn by horses to execute a given number of miles on your trust? I once, by mere acci-

dent, came in the Leeds Union coach from Grantham, which is 110 miles from London; I got into the coach at three o'clock, and I was in London at half after one the same morning; that was at the time the Leeds Union and the Rockingham were racing the whole way up.

Are you aware that Mr. Telford states in his report on the state of the Holy head roads, that three of the Birmingham coaches perform the journey of 110 miles in less than eight hours, without any accident, at the rate of thirteen miles and six furlongs an hour? I have frequently heard it stated upon the road, though I do not know it of my own personal knowledge.

Have you any other observations you would wish to make to the committee? I am not aware of any point.

You do not think it will be necessary to limit steam carriages to any particular number of passengers, provided the wheels were of the dimensions stated? If the wheels were of the dimensions and the description stated, I should, in reason, be regardless of weight, experience having completely proved, with properly constructed wheels, we sustain little or no injury from weight.

What is the maximum weight a road would bear upon each wheel? The injury done by weight upon a road in a carriage with proper wheels is principally, I might almost venture to say exclusively, to the new coatings; if the weight in such carriage is a crushing weight, as applied to the materials with which the road is made, it does a very considerable injury, and therefore were steam carriages to become in general use, it would be a matter of great importance, that harder material should be introduced, that flint should take the place of gravel, and that granite or whinstone take the place of flint, which is the principle acted upon by the commissioners of the Metropolis roads; but, upon a hard and well consolidated road, a very great weight may be sustained without doing comparatively any injury.

When you state that if steam carriages come into general use harder materials ought to be used, you suppose that these steam carriages will be much heavier than the carriages used at present? Yes; I contemplate that they will carry much greater weights.

Your answer does not apply to carriages that are of the same weight as those now used? No; but to carriages of the weight of eight or ten tons; when I spoke of the weight of from eight to twelve tons, I supposed a carriage with four wheels.

Upon the present well constructed roads, what weight do you think could be put upon them without crushing them? I should not apprehend any injurious result from the general use of steam carriages with properly made wheels, carrying upon an average from eight to ten tons.

Your answer refers to roads that are so well made that the whole pressure shall be as that of an arch, but on the average of roads, such as shall be found in the country, would you give the same answer? No, certainly not.

Taking the average of any line of road for a great number of miles, where materials less capable of bearing weight must necessarily be used for a considerable proportion of that road, what should you say is the maximum weight that should be allowed with reference to the preservation of that road on any one wheel of four inches and a half? Two tons.

Have you ascertained that by experiment? I have not had an opportunity of judging of it, except in all the wagons that depart from the Metropolis that are required to have the wheels constructed in the way I have described, some of which carry considerable weights.

Martis, 6° die Septembris, 1831.

Mr. *John Macneil,* civil engineer, Daventry; called in, and examined.

State your profession? A civil engineer; I am at present the resident and assistant engineer, under Mr. Telford, to the Parliamentary commissioners on the Holyhead road between London and Shrewsbury, and London and Liverpool.

What is the weight, of a coach, a van and a wagon, each carrying what would be considered an average load; state also the breadth of the tires of their wheels? The weight of four horse stage coaches vary from fifteen cwt. and three quarters to eighteen cwt.; most of the Birmingham day and night coaches weigh about sixteen cwt., and frequently carry, the night coaches in particular, upwards of two tons of goods and passengers, exclusive of the coach; yet, taking into consideration the number of times they travel with very light loads, I should say that from two tons five cwt. to two tons ten cwt., including the carriage, would be a fair average weight during the year. The tires of the wheels are mostly two inches, but some of them are less; those constructed by Mr. Brown, and used on his patent coaches, have the edges chamfered off, so as to give a flat bearing of one inch and a half, but from the peculiar manner in which those coaches are mounted with springs, I am inclined to think the injury done to the roads by these wheels is not so great as it otherwise would be. Some coach wheels that I have seen are rounded off, so as to form in the cross section a segment of about one inch and three quarters in diameter. The bearing in this case on the road, where the surface is hard and smooth, is reduced almost to a point, and must be extremely injurous. The coachmen remark that carriages with such wheels run wild in descending hills in summer, but heavy in winter, and when the roads are soft and muddy. The mail coaches weigh very nearly twenty cwt. Some of them, the Holyhead coach for instance, frequently carries upwards of a ton of letters and parcels, independent of passengers and their luggage. The average weight of the whole may probably be taken at two tons. Some others, the Liverpool day mail for instance, travel very light, and probably will not average one ton and a half. The breadth of tire of mail coaches is two inches and a quarter; the four horse vans, which travel about six miles an hour, weigh on an average four tons and a quarter, including the carriage; the breadth of tire of one which I measured was two inches and a half, but I am not prepared to say that this is the general size of such wheels; the horses used in these carriages are of the very best and largest description, which, added to so great a weight on narrow wheels, probably renders this carriage more injurious to the public roads than any other description of vehicle at present employed. There are four descriptions of wagons in general use, the eight horse wagon, the six horse wagon, the four horse wagon, and the farm wagon, which is drawn sometimes by two, three or four horses, according to the load. The eight horse wagons, though frequently weighing, with the load, seven tons, may probably be averaged at not more than six tons the year round; the wheel is nine inches in the tire, but, from a very improper plan followed in its construction, the bearing on a hard solid road is only three inches, for these wheels are generally shod with three hoops of three inch iron, the centre one of which is of a greater diameter than the others, and projects full half an inch beyond them, which, on weak roads, such as in the neighborhood of London, must be most injurious. I have measured one since I came to

London, which travels on the Bath and Bristol road, the outer rim is conical; and can certainly never come in contact with the road surface, unless it be one on which the wheel would sink two or three inches. The section of the wheel is represented in the following sketch:* the six horse wagons, with their load, generally weigh four tons and a half; their wheels are six inches wide, and of a better description than the former, though sometimes one of their hoops projects beyond the other, as in the case of the nine inch wheel; the four horse wagons, with their load, commonly weigh three tons and a half, their wheels are four inches wide, and are more upright than the others, and have a more level bearing on the road; the farm wagons, used in Northamptonshire, weighs, on an average, one ton one cwt., the breadth of a wheel is three inches, and it carries from one ton to three tons, according to circumstances, and lasts nearly twenty years.

On an average line of road of not less than 100 miles, on which, in many places, materials of very inferior description must have been used, both in its formation and subsequent repair, what is the maximum weight per wheel (say if not less than four inches width of tire,) which should be carried on any kind of carriage (carriage weight included,) without risk of injury to the road? On a road, such as here described, the injury will be considerable by any wheel passing over it; but without a more defined statement of the quantity and quality of the materials used, I do not think this question can be answered with any degree of certainty. On all gravel roads, however, made, without a foundation or bottoming, I should say the weight, on a four inch wheel, should not exceed fifteen cwt., and on a wheel less than that ten cwt. on the generality of roads, throughout the country, I do not think it would be safe to run a carriage with almost any width of wheel if the load much exceeded ten tons; in fact there are some bridges even between London and Birmingham, that it would be running a risk to pass over with a carriage weighing ten tons.

Can you, from observation, say what proportion the breadth of the tire of wheels should be to the weight? The breadth of tire in proportion to the weight, will depend entirely upon the description of road over which the carriage passes; on such a road as that lately constructed by the parliamentary commissioners of the Holyhead and Liverpool roads, at the Highgate Archway, I have frequently observed wagons, carrying upwards of six tons pass over it; the weight of each wheel on the road was then about thirty cwt.; and though the bearing of the wheels, from the cause I have before stated, was not more than three inches, the effect produced was imperceptible. The pressure, in this case, was ten cwt. on every inch, which is unquestionably too much for the generality of roads; but if we take the road from London to Shrewsbury, as a criterion to judge by, I should say that a wheel ought to be an inch in width for every ton that a carriage and its load would weigh; and that if every carriage that now travels that road, was limited not to exceed that proportion, the roads would be better, and maintained at a cheaper rate than at present. According to the average weight of coaches and wagons, as before stated, I have calculated the following table, showing the weight at present carried on each inch of bearing, and what I conceive might be the breadth of the different wheels if they were made cylindrical with an even bearing, and in the proportion of one inch of width for every ton including the carriage.

Description of carriage.	Velocity in miles per hour.	Weight, on an average, in tons.	Breadth of the wheels, in inches.	Pressure of each wheel, in cwts.	Pressure on each inch, in cwts.	Breadth of wheel, calculated in the proportion of 5 cwt. to the inch.
Mail coach	9 to 11	2	2¼	10.0	4.40	2
Stage coach	8 to 11	2½	2	12.5	6.25	2½
Van	6 to 7	4¼	2½	21.25	8.29	4¼
Wagon	2½ to 3	6	9	25.0	2.77	6
Ditto	2½ to 3	4½	6	22.5	3.75	4½
Ditto	2½ to 3	3½	4	17.5	4.37	3½

State your opinion as to the relative wear of a road by two carriages, both drawn by four horses, one carriage of two tons weight, with two inch tires, the other four tons, with four inch tires? My opinion is, that the wear of the roads would in each case be the same, as far as it was affected by the wheels of the carriages, probably rather less, by the carriage carrying four tons, on four inch wheels, than by the carriage carrying two tons, with two inch wheels; but it must be recollected that both the carriages are supposed to be drawn by the same number of horses, and as the horses drawing the carriage of four tons, must use greater exertions than those drawing the carriage of two tons, I am of opinion that the aggregate wear of the road would be more by the transit of the four ton carriage, than by that of the carriage weighing two tons.

How would the foregoing answer be affected by an increase or decrease of velocity in either carriage? If the road over which the carriages are drawn be hard, solid and smooth, I think there would be very little increase of wear from the effect of the carriage wheels by an increase of velocity; but if the road should be uneven or rough, there would be an increase of wear, in consequence of the impetus or blow with which the wheels would strike the road after passing over the inequalities in its susface, particularly if the carriages were made without springs; but whether the road be a good or a bad one, the wear occasioned by the feet of the horses will be greater when they travel with an increased velocity: for a coach-horse which travels at the rate of ten miles an hour, works on an average 270 miles in a month, and wears out in that time about four pounds of iron in shoes; whereas a wagon horse, which travels at the rate of three miles an hour, and works twenty-six miles a day, for four days in the week, goes, on an average, 416 miles in the same period of time, and wears out 4.8 pounds of iron. If the coach-horse travels the same distance, the wear would be six-sixteenths, which exceeds the wear of the wagon-horse one-thirty-sixth. In the same way might the relative injury caused by the wheels of the wagon and the coach be ascertained.

What is the operation of the atmosphere on roads? Well made roads, formed of clean hard broken stone, placed on a solid foundation, are very little affected by changes of atmosphere; weak roads, or those that are imperfectly formed with gravel, flint, or round pebbles, without a bottoming or foundation of stone pavement or concrete, are, on the contrary, much af-

fected by changes of the weather. In the formation of such roads, and before they become bound or firm, a considerable portion of the sub-soil mixes with the stone or gravel in consequence of the necessity of putting the gravel on in thin layers. This mixture of earth or clay, in dry warm seasons, expands by the heat, and makes the road loose and open: the consequence is, that the stones are thrown out, and many of them are crushed and ground into dust, producing considerable wear and diminution of the materials; in wet weather also, the clay or earth, mixed with the stones, absorbs moisture, becomes soft, and allows the stones to move and rub against each other when acted upon by the feet of horses or wheels of carriages. This attrition of the stones against each other, wears them out surprisingly fast, and produces large quantities of mud, which tend to keep the road damp, and, by that means, increases the injury.

Supposing the actual wear or deterioration of a road to be represented by 100, and that only coaches, vans and wagons have passed over it during any given period, in what proportion would you estimate the effects; first, of atmosphere; secondly, of the carriage; thirdly, of the horses? This question can only be answered in a general way; no two lines of road would probably give results at all similar; much will depend on the manner in which the road is constructed, the materials of which it is composed, the care bestowed on its drainage, and whether it be in an open situation or shaded by trees. If the road be properly made, and in an open situation, the injury arising from the atmosphere will be little, compared with the actual wear caused by the wheels of carriages and the feet of horses, probably not ten per cent. during the year; whereas, on weak roads in clay countries, every shower loosens the materials of which the road is composed, and causes considerable wear, perhaps thirty per cent. or even more in some situations, where the road is shaded by trees; to get at something like an average proportion between the wear occasioned by horses' feet and the wheels of carriages, I have procured the following facts: the coaches which run between London and Birmingham, require an hundred horses on an average, to work the up and down coach; the horses are generally shod by contract, at about 2*s.* 6*d.* per horse per month; those near London are much larger and heavier, and therefore require heavier shoes than those twenty miles out of London, and from thence to Birmingham; near London, in the flint districts, the wear of horses' shoes is much more than it is in the quartz and limestone countries. At Stony Stratford, the weight of the four shoes of a mail and stage coach-horse averages five pounds, and when taken off at the end of about twenty-eight days, they weigh very nearly two pounds: in this period, the horses run 252 miles. At Towcester, Weedon and Daventry, the weight of the new shoes is one pound and a half each, and, when taken off, weigh nearly three-fourths of a pound; the length of time which they remain on is about thirty days; this would give a wear of three pounds per horse per month, but if the greater wear near London be considered, I think it would not be too much to allow the wear equal to four pounds per horse per month, which, for 100 horses for ten weeks, would give a wear of 1,000 lbs. of iron. The hind wheels of the coaches are mostly four feet eight inches in diameter, and the front wheel three feet. The width of tire, I before stated is about two inches, and when new, the thickness of the iron is three-quarters of an inch. These wheels are found to last from two to three months, according to the state of the weather, the workmanship and quality of iron, (about twenty years ago they did not last seven

days on an average;) suppose they now last ten weeks, in that time the tire is worn down to one-sixth of its original thickness. This would be equal to 163.4 lbs. or 326.8 for both coaches; this would be to the wear of the horses' shoes as 326.8 to 1,000, or as 1 to 3–14ths nearly; now if the injury done to the road by the horses' feet and the wheels of carriages be estimated in the same proportion, I think it would probably be near the actual effect produced; that is to say, the injury done by the wheels of fast coaches is to the injury done by the horses which draw them as one to three in round numbers. The effect produced by slow carriages and horses is different: a wagon drawn by four horses, which travels regularly from London to Daventry at the rate of three miles an hour, is worked by fifteen horses; the wagon weighs twenty-five cwt. and carries, on an average, sixty-seven cwt.; the hind wheels are four feet eight inches in diameter, and the front ones four feet; the breadth of the wheels is six inches; they are nearly upright but not cylindrical. The iron tire, when put on, weighs on the fore wheel, 285 lbs., on the hind ditto, 396 lbs., making 621 lbs. When removed, the weight is on the fore wheels, 144 lbs., on the hind ditto, 168 lbs., making 312 lbs.; wear in five months, 309 lbs. The number of miles travelled in this time is 6,048; the shoes that are put on the horses employed to draw this wagon, weigh, when new, from two pounds and a half to three pounds each; the average of a great many gave two pounds and three quarters, and when removed one pound and a quarter. They last from four to six weeks, according to the weather and state of the road; but we may assume five weeks as an average, and the wear in that time for each horse six pounds, and for fifteen horses for five months, it would be 360 lbs. The proportion in this case would be as 309 to 360, or as one to 1.16, or nearly one to 1¼ on the generality of roads: therefore, I would say the proportion of iujury would be nearly as follows, when travelled by fast coaches:

Atmospheric changes - -	20
Coach wheels - - -	20
Horses' feet that draw them - -	60
	100

and when travelled by wagons:

Atmospheric changes - -	20
Wagon wheels - - -	35·5
Horses' feet that draw them - -	44.5
	100*

What is the effect of travelling by coaches and horses; whence, and in what proportion, does the injury or deterioration arise; the crushing of materials; their actual wear; their displacement? If the wheels of carriages be properly constructed, and cylindrical, the friction, and consequently the wear on the surface of a well-made road, will be very little, and there will be no injury from displacement of materials, except what may arise from the few surface-stones that will sometimes be started out by the feet of horses on steep hills, when they are obliged to exert a great force to draw up a heavy load. When stones are thus thrown out on a hard and solid surface, the wheels of heavy carriages will crush them, and cause an injury which would be much more than that caused by the actual wear of the wheels pas-

sing over the surface. If the roads be weak or elastic, and bend or yield under the pressure of the wheels, the particles of which it is composed will move and rub against each other, or perhaps break by the action of heavy wheels over them. On such roads, I conceive the injury caused by steam carriages will be much greater in proportion to the injury caused by light carriages drawn by horses, than it will be on solid firm roads. In one instance, where an accurate experiment was made, the wear was found to be four inches of hard stone, when it was placed on a wet clay bottom, while it was not more than half an inch, on a solid dry foundation, (formed as described in the report of the select committee on the Holyhead road, on the 30th May, 1830,) or with a pavement bottom, on a part of the same road, when it was subject to the same traffic. On the Highgate archway road before mentioned, the annual wear does not appear to be more than half an inch in depth. Now, as this road is very little affected by wet, in consequence of its peuliar construction, and the care bestowed on its drainage, I attribute almost the whole of the diminution of materials to actual wear. On many roads, where the sides are weak, great injury arises from the crushing of materials, particularly by the action of wagon-wheels. In frosty weather, weak roads very frequently suffer more in one month than all the rest of the year. In such cases, the injury is caused by the wheels of carriages, and not by the horses' feet.

If 30 lbs. be sufficient to move a carriage of 21 cwt. 8 lbs. on a level platform, little affected by friction, and 266 lbs. be required to move the same carriage up an inclination of 1 in 10, the pressure in the one case being exactly the weight of the carriage, 21 cwt. 8 lbs., what would be the pressure on the road, or platform, on the inclination?—As the pressure on the horizontal is to the pressure on the inclined plane, as the length of the plane is to its base, we have this proportion, $\sqrt{b^2+p^2}:b::\mathrm{W}:\dfrac{\mathrm{w}b}{(b^2+p^2)^{\frac{1}{2}}}=$ the pressure on the plane. In this example, $\mathrm{w}=2360.\ b=10.\ p=1$, which gives $\dfrac{\mathrm{w}b}{(b^2+p^2)^{\frac{1}{2}}}=\dfrac{2360\times 10}{\sqrt{100+1}}=2349.5$ lbs. or $10\frac{1}{2}$ lbs. less than the pressure on the horizontal.

Taking twenty miles near London, 150 lbs. appears to be the average force actually engaged in drawing the carriage of 21 cwt. 8 lbs. including hills, would the force required to draw a carriage of 42 cwt. 16 lbs. be on an average 300 lbs. and so on in proportion?—the extreme traction of the carriage being 343 lbs. what, on this road, would have been the maximum force required to draw a carriage of four tons weight? It does not follow that because a carriage is twice as heavy as another, that its draught would be twice as much. The resistance arising from gravity on the inclined planes would, abstractly considered, be double, but that part of the resistance arising from the friction and penetration of the wheels into the surface materials, would much depend on the construction of the carriage, and its wheels, and the different sorts of roads over which it was drawn. In order to ascertain the average draught of a carriage of 42 cwt. 16 lbs. over the above road, I conceive that the friction of the surface or resistance opposed to the motion of such a carriage, should be ascertained on each description of road within the above limits, and then by knowing the rates of acclivity, or the amount of gravity acting on each, the average draughts might be ascertained, if the same carriage and wheels were used, but loaded so as to make

up 42 cwt. 16 lbs. the average draught. It might probably be calculated pretty nearly from the following table of experiments, which, as it may be of use in the present inquiry, I here beg leave to hand in; but it must be remembered that the proportions given in this table between the increase of weight and the increase of draught, will not be the same on every description of road. To be enabled to answer the second part of the question, it will be necessary to know the rate of acclivity on which the draught of the carriage weighing 21 cwt. 16 lbs. was 343 lbs., and also to know the draught of the four ton carriage on the horizontal; but even then a difference might arise from the construction of the carriage, and the situation of its centre of gravity.

TABLE of Experiments made on the 28*th January,* 1829, *immediately after a rapid thaw: the mud was full one and a half or two inches thick on the road at the time.*

TABLE I.

No. of Planes.	Wagon empty, weight 1 ton.		Half a ton in the wagon.		1 ton 2 cwt. in the wagon.	
	Down.	Up.	Down.	Up.	Down.	Up.
1	30	99	45	145	58	210
2	64	88	105	120	125	150
3	75	85	115	120	135	155
4	75	85	105	115	135	155
5	80	88	105	125	135	165
6	85	93	105	135	135	170

Neither the rates of acclivity, or the lengths of the planes, were taken at the time, but it might still be done, if thought necessary by the committee, as the points are well ascertained.

Experiments made on a horizontal timber platform in January, 1829.

TABLE II.

Weight of the wagon and load.	Powers required in lbs. to move it.	Difference between empty wagon and load.
2,240	29	
2,800	74	45
3,360	104	75^{30}
3,920	140	111^{36}

If 266 lbs. be required to move a carriage of 21 cwt. 8lbs. up an inclined plane of one in ten, what amount of weight would be required to keep the

carriage stationary, or to allow it to descend with the slowest possible motion on the same inclination?—this question has reference to the injury done to the roads by "dragging" the wheels, and subsequently to the slow motion of the propelling wheels of steam carriages in descending hills. If the base of the inclined plane be 10, and its height 1, the length will be $\sqrt{10^2+1^2}=\sqrt{101}=10.05$ nearly, and we have the proportion $10{\cdot}05 : 1 :: 2360 : 234{\cdot}82$ lbs. the weight which would be required to keep the carriage stationary if the surface of the plane was hard and smooth, and the mass collected in a point; but, as 266 is stated to be the moving power, the resistance arising from the friction of the surface, and the axle trees, would, in this case, be 31.18 lbs.; it may be well to observe here, that the experiments made on inclined planes, as detailed in the seventh report of Parliamentary commissioners of the Holyhead and Liverpool road, were not intended for any thing further than to get practical results, the description of which could be easily understood by road surveyors and their assistants, and even by men in the habit of driving coaches. It could not be expected that experiments made with a large unwieldy wagon, mounted with common axle-trees besmeared with tar, could furnish results on which to found a refined mathematical calculation. I have, however, within these few days, commenced a series of experiments, with a small carriage constructed on purpose, and furnished with a very delicate instrument for measuring the draught. From the little way I have as yet gone in these experiments, I cannot furnish any details at present; but I think I am warranted in saying that a very great benefit would arise in the saving of road materials, by the adoption of a better method of hanging the coaches, in a manner, perhaps, something similar to gentlemen's carriages. Many of these weigh, when fully loaded, two tons, yet a pair of post-horses draw them, with apparent ease, the rate of ten miles an hour; and, on some parts of the road between London and Birmingham, where the road is tolerably level, at a much greater speed: some of the Birmingham and London coaches travel the same ground, at twelve miles, and sometimes fifteen miles an hour. This velocity, however, may, in a great measure, be attributed to the level and perfect state of that road.

The details of various kinds of steam carriages have been given to the committee; all act without propellers; without projection on the wheels, with cylindrical wheels; some with greater or less breadth of tire, even six inches wide; the power is applied either by crank or wheels to one or two propelling wheels, according as greater or less force may be required. Some of the experimental carriages had three, some six wheels; all will have four wheels. Some have the engines in a separate carriage, and draw the load; some carry the load and engines on one carriage. Taking the above circumstances into consideration, which would be most injurious to a road—a stage coach, drawn by four horses, weight of coach three tons, horses two tons, breadth of tire two inches and a half; or steam coach, wheels four inches tire, weight four tons; in both cases velocity ten miles per hour? Taking for granted that the injury which a road sustains by the wheels of carriages and the feet of horses is proportional to the wear of iron on the wheels and on the horses, and that the statement before given as to the actual wear on each be found correct, I would say the injury done to the road by the steam carriage weighing four tons with four-inch wheels, would be less than that occasioned by the coach weighing three tons, drawn by four horses.

Would it be beneficial or otherwise to the roads, that steam carriages: drawing heavy weights in carriages attached to them, should be substituted for wagons drawn by horses, supposing that the weight of the drawing or propelling carriage should not in any case exceed the weight of the number of horses that would have been used to draw a corresponding weight, *e g.*

Wagon - - - -	8	tons
Eight horses, 15 cwt. each -	6	ditto
	14	
On steam carriage - -	4	
Carriage drawn - - -	10	
	14 ?—	

I am of opinion, that if the steam carriage and its accompanying carriage be constructed with wheels of a proper width, and of the same diameter as the wagon wheels, and travel with the same velocity, that the injury on well-made solid roads will not be more than that caused by the wagon and horses: in fact, if the proportion of injury before stated be correct, it will be less; but it must be recollected that weak roads suffer more than solid ones from the heavy pressure of wheels, and, in such cases, the steam carriage and its tender would be more injurious.

In descending hills, steam carriages can regulate their velocity by reducing the action or number of revolutions of the wheels; this acts as a drag, but with the advantage to a road that the wheel moves continually round; which would be most injurious to a road, the descent of a carriage dragged as usual (not omitting the operation of horses' feet,) or the steam carriage dragged or regulated in the mode described? Not having seen a steam carriage descending a hill in the manner described (that is, regulated by the action of the engine on the wheel,) I cannot give a satisfactory answer to this question; but, as far as opinion goes, I should say that the joint action of the horses and drag would be more injurious than the steam carriage, the motion of which was regulated in the above manner, provided the wheels were of the proper width, and the total weight not greater than that of the coach and horses.

Various local acts have passed, placing excessive tolls on steam carriages—it may be requisite to introduce a general bill, which shall, on such roads, place steam carriages on a fair equality (so far as their relative injury or wear of road, to common coaches on each such road; the toll on a coach on such roads may vary fron one to two shillings, according to local circumstances, on a wagon in the same proportion; what standard of charge would you suggest for steam carriages? It has been stated to us, that one steam carriage has drawn a carriage containing as many as thirty passengers at the rate of even ten miles per hour, and nine tons weight at the rate of five miles per hour, but with smaller wheels, what regulation would you suggest as to the breadth of tire, or should tolls be chargeable in inverse proportion to the breadth of tire? The toll which carriages propelled by steam, or by any other mechanical means, should be required to pay, ought, in my opinion, to be in proportion to the injury they would do to the roads compared with that done by the present description of carriages and the horses employed to draw them, without reference to the weight or quantity of

goods carried; but, as I before stated, I do not believe an accurate estimate can be at present formed as to the injury that roads may sustain from steam carriages, compared with the injury done to them by coaches drawn by horses. It may, however, I think be safely assumed that the injury done to a road by a steam carriage would not be greater than that occasioned by a stage coach drawn by horses, the weight of the engine and its load being supposed not to weigh more than the stage coach, together with its load and horses. If this be granted, and an act passed limiting the width of wheel in a certain proportion to the weight carried, there would not be much difficulty in arranging a scale of tolls applicable to steam carriages, which would put them on an equitable footing with carriages drawn by horses. If, for instance, a proportion, such as I have already mentioned be adopted, viz. that a wheel should be an inch in width for every 5 cwt. it has to support, and a toll charged for each inch equal to the amount charged for a horse drawing in a carriage which travels with the velocity of the engine, it would, in my opinion, be a fair and equitable toll, at least for some years, or until a correct proportion of injury was ascertained by experience and observation, when it might be altered or amended according to circumstances. This mode of charging toll would be extremely simple, and not likely to be misunderstood by toll-collectors, or to occasion any disputes; but there should be a heavy penalty attached to the proprietors of steam carriages if they put a greater weight on the carriage than the wheels were intended to carry. If the engine, instead of carrying the load, draws one or more carriages after it, the toll should be collected and charged on each carriage in a similar manner as it is charged on the engine, that is, in proportion to its wheels. An example will illustrate my meaning more clearly: suppose an engine, together with its load, to weigh nine tons (which is about the average weight of two stage coaches, including the weight of the horses which draw them) to pass through a toll-gate where horses drawing coaches are charged 6*d.* each, the toll on the two coaches, would be 4*s.*, and of the steam carriage 4*s* 6*d.* Suppose that the engine, instead of carrying the load, draws a carriage after it, and that the weight of the engine is five tons, with five-inch wheels, and of the accompanying carriage four tons, with four-inch wheels, the toll of the engine would be 2*s.* 6*d.*, and of the tender 2*s.*, making 4*s.* 6*d.* as before. The only objection I can see to this mode of charging toll on steam carriages travelling over the turnpike roads, would be, that, in the event of their being able to carry a greater number of passengers at a cheaper rate than the present description of carriages drawn by horses, it would lessen the amount of toll collected as a fewer number of carriages would do the work, and many persons who drive their own horses would travel by them if found cheaper to do so; and this circumstance, although it would not affect the state of repairing in which the road was previously maintained, it might lessen the value of property invested in the different turnpike trusts throughout the kingdom, which is a very considerable sum; but such circumstances should not militate against an invention likely to prove beneficial to the country at large.

Give your opinion on the probable extent of injury to roads from steam carriages? Generally speaking, I should say that the injury roads will sustain by the introduction of steam carriages will be much less than is commonly supposed; but the actual amount of injury, or correct estimate of the comparative injury that will be done by a steam carriage, cannot, in my opinion, be formed at present with any degree of certainty. Experience

alone will decide the point. The only danger, in my mind, that is to be apprehended, is the injury which roads may sustain by the possibility of the wheel which is acted upon by the engine, turning round without propelling the carriage, in which case the road would suffer considerably; and this would take place if a train of carriages were attached to the engine, the draught of which was more than the friction or gripe of the engine wheel on the surface of the road. As long, however, as the weight is carried by the engine, and not drawn after it, nothing of this kind will take place even on our steepest hills.

Have you communicated you conclusions on these subjects to Mr. Telford? I have.

Does he coincide with you? Quite so.

You stated that the only probable injury to the roads from travelling of steam carriages, would be the slipping of wheels; would it not be directly against the interest of the proprietor that the wheels should slip in any degree, there being a necessary loss of power every time they do slip? Clearly so.

From your observations of the effects produced by heavy carriages drawn by horses in ascending and descending hills, what would be the effect, under similar circumstances, of a steam carriage of weight equal to the weight of the coach and horses? I am of opinion that the effect or injury to a road would be less by the steam carriage; for when hills exceed a certain rate of inclination, gravity overcomes the friction of the surface, and the carriages, in descending, press upon the horses, unless a drag be applied to one of the wheels. This, in itself, injures the road, but not so much as when no drag is used, because the horses are then obliged to bear against the carriage, and set down their feet very strongly: this often tears up the surface, particularly of weak roads. The time that is lost by the coaches in descending some of the hills on the road between London and Birmingham, is full as much as is lost in ascending them, besides the imminent danger, even with the greatest caution, on the part of the drivers. If proper springs were used, the draught would be lessened, and of course the injury to the road would be much diminished.

On every road there are numerous six horse wagons; you state the weight to be four tons and a half, the horses weighing four and a half more, making nine tons—should any objection be taken to a single steam carriage of this weight, or from nine to ten tons, provided the wheels be of a proper description? No; I think in the general state of roads, a steam carriage of from nine to ten tons could run with perfect safety, without injury to the roads, if it was constructed with proper wheels.

The above question refers to a steam carriage carrying its load; if the engine carriage were of the weight of four tons, drawing a second carriage of the weight of six tons, thus dividing the weight over eight wheels, would the effect on the road be less injurious, provided it was four and a half tire? I think the injury would be less, provided the engine had the power to propel itself, and draw a carriage with six tons after it, without a slipping of its wheels.

Carrying this principle further, if the load were divided into two carriages, each to weigh three tons, thus dividing the load over twelve wheels, would not less injury still be done? Decidedly; particularly on weak roads.

If, under these circumstances, you can diminish the pressure on the road by

multiplying the number of wheels, should not care be taken so to frame the tolls to be levied as not to discourage the use of those steam carriages, whose greater number of wheels could be least injurious to the roads? I think that would be regulated by the mode I have suggested of charging toll.

Have you seen Mr. Gurney's carriage, and examined its effect on the roads? I have seen it.

What state were the roads in, at what velocity was it going, how many persons did it carry, and what was its weight? I do not know the weight of the carriage, there appeared to be eight or ten people on and about it; the road on which I saw it was excessively bad, one of the worst in the country; the velocity was probably five or six miles an hour.

Were there other loaded carriages passing along the road at the same time? Several; both coaches and wagons.

Did you remark the effect of the steam carriage on the road, to see that it did less or greater injury than the other carriages? I could not perceive any difference.

If there had been any great difference, you would have perceived it? As far as leaving a track behind, which would have been perceived, I could not ascertain the amount of injury: it was nothing more than that done by common coaches.

Do you think it essential that the wheels of steam carriages should follow in the same track, provided they have a proper breadth of tire? Not at all as regards the injury to the road; it would require more power to work them if the wheels did not follow in the same track.

Supposing the steam carriages, either the propelling carriage and the carriage drawn, or the engine carriage carrying the passengers, were generally to be four tons, what would you recommend to be the minimum breadth of tire to either of the carriages? In the present state of steam carriages, as applied to the working over turnpike roads, I should say you might limit them to not less than four inches for a few years.

Supposing their average weight never exceeded from six to eight tons, do you think four and a half would be a safe minimum? I am inclined to think it would be rather too little.

Do you think it would be necessary to make any alteration in the form of the present line of turnpike road for the facility of working by steam? I do not think it would be absolutly necessary: it would, however, be of great benefit to the country and every person in it, if the hills on the present lines of road were more reduced, and the surface strengthened. No road should have a greater ascent than one in thirty or one in thirty-five; in almost every instance the expense would be saved in horse labor in a few years. The following table will show pretty nearly the increase of expense in transporting goods by stage coaches drawn by horses up planes of different rates of ascent. Roads in general have, in some parts, steep ascents; one in fifteen between this and Birmingham, for instance, is too much on a road of such traffic. The surfaces are not so good generally as they ought to be; the roads should be strengthened, either with a pitched bottoming of stone, or a concrete mass, such as the Highgate archway, or the new road near Coventry.

TABLE.

Expense of drawing one ton over one mile at different rates of acclivity, by a stage coach and wagon.

Four-horse stage coach, average velocity 10 miles per hour.		Wagon, four horses, average velocity 2½ miles per hour.	
Rates of acclivity.	Pence and decimals.	Rates of acclivity.	Pence and decimals.
	d.		d.
1 in 10	77·24	1 in 10	52·07
1 in 15	57·78	1 in 15	28·70
1 in 20	50·47	1 in 20	22·83
1 in 30	44·15	1 in 30	18·55
1 in 40	41.25	1 in 40	16·79
1 in 50	39·56	1 in 50	15·82
1 in 60	38·46	1 in 60	15·20
1 in 70	37·68	1 in 70	14·77
1 in 80	37·09	1 in 80	14·46
1 in 90	36·64	1 in 90	14·22
1 in 100	36·28	1 in 100	14·04
1 in 150	35·19	1 in 150	13·46
1 in 200	34·64	1 in 200	13·18
1 in 300	34·09	1 in 300	12·91
1 in 500	33·65	1 in 500	12·69
1 in 1,000	33·32	1 in 1,000	12·53
Horizontal	32·98	Horizontal	12·36

What would be the difference of expense of pavement, and forming a good granite road, in the neighborhood of London; say twenty miles? If you take twenty miles, and also take the repairs of the roads for twenty years into account, I should say paving would be the cheapest. The great defect of all the London pavements arises from want of a strong and firm foundation. In Fleet-street, and some others, this has been partly accomplished of late, but certainly not as perfect as it might be. If on the road from this to Birmingham there was a portion laid off on the side of the road for steam carriages, which could be done without difficulty, and if it be made in a solid manner with pitching and well broken granite, it would fall very little short of a railroad. My only reason for keeping it distinct from the other road, is the evident injury every road sustains from horses travelling over it and breaking up the surface, and the steam carriages would be able to go with greater velocity if they were not interrupted with droves of cattle; besides, it would be easy to fence it off from fifteen to twenty feet, without injury to property; and the expense of making a solid road of twelve or fifteen feet would not be very considerable.

But have you any doubt whatever that steam carriages can be brought into practical use, with great benefit to the public, even on the present lines of turnpike roads? I am quite convinced they can.

Would the wear of such roads as you have described be much affected by the greater or less velocity of the steam carriages? It would be hardly affected at all, on a good road, by increased velocity; if any thing, perhaps rather less.

Do you propose in your scheme of toll that weight should be the basis of toll, but that the wheel be an index to the weight? Yes, that is the principle on which I have suggested the scale of tolls.

How would you check the frauds of proprietors of steam carriages by their placing a greater weight in proportion to the breadth of tire? I conceive the use of the steam carriage would be for passengers solely and their luggage: if the weight was ascertained in the yards at London, Birmingham, or Shrewsbury, the intermediate trafic would differ very little, for persons going short distances would go by the coaches as at present.

Would you suggest that a license should be granted to steam carriages, limiting the number of passengers they should take in proportion to the breadth of tire of the wheel? I think it would be quite as much as the road trustees could expect; and by marking in large characters the width of wheel on the carriage, it would be a great preventive to the proprietors altering the wheels.

Do you think that, considering the infant state of this invention, that the road trustees would practically suffer any great injury or inconvenience by merely, for two or three years, placing steam carriages, whatever weight they may be, on a level with ordinary carriages, with reference to the toll charged for them? Considering the present imperfect state of steam carriages for turnpike roads, I think it would do no injury to road trusts if such a regulation was adopted.

Would you place steam wagons on the same footing as wagons drawn by horses? Yes, provided the wheels are made, as I described, in proportion to the weight; there should be the same toll on a wagon drawn by steam as a wagon drawn by horses, that is, the width of wheel should be charged per inch as the horses are now charged.

Should a steam wagon be licensed, as to its weight, in the same manner as a steam coach? I think just the same.

Did you conduct the experiments made on the Holyhead road as to the force of traction required on different inclinations? I did.

Were they carefully made or otherwise? They were carefully made as far as the materials would allow; the wagon was a very large one, with common axle-trees; the result in some cases differed from two to three pounds; on the whole, I should say the results stated in that report do not exceed in any case five pounds beyond what they would be found if proved by the best practical instruments, and are confirmed by my subsequent observations and experience. The object we had in view, by these experiments, was to show to the trustees and the surveyors of the roads, that a road might appear a very good one, and still not be one adapted for traffic. By these means they have perceived the defective parts in the road; and within three months after the report of the Parliamentary commissioners became public, there was not a hedge on that part of the road where the draught was shown to be excessive, that was not cut down, and improvements made on the surface.

When you followed Mr. Gurney's carriage, did you perceive that any horses were frightened, or any inconvenience arose to passengers on the road? I did not perceive the least inconvenience. I saw several horses pass, both gig and saddle-horses, also coaches, and not one took the least notice of it.

Veneris, 9° die Septembris, 1831.

Colonel Torrens, a member of the committee, examined:

Have you considered the effect which will be produced upon British agriculture, by substituting, on common roads, steam carriages for carriages drawn by horses? I have.

What do you conceive that effect would be? I think it would produce very beneficial effects upon agriculture.

State your reasons for believing that agriculture will be benefited by substituting inanimate for animal power, consuming the produce of the soil? I conceive that agriculture is prosperous in proportion as the quantity of produce brought to market exceeds the quantity expended in bringing it there. If steam carriages be employed instead of carriages drawn by horses, it will be because that mode of conveyance is found the cheapest. Cheapening the carriage of the produce of the soil must necessarily diminish the quantity of produce expended in bringing a given quantity to market, and will therefore increase the nett surplus, which nett surplus constitutes the encouragement to agriculture. For example, if it requires the expenditure of two hundred quarters of corn to raise four hundred, and the expenditure of one hundred more on carriage, to bring the four hundred to market, then the net surplus will be one hundred. If, by the substitution of steam carriages, you can bring the same quantity to market, with an expenditure of fifty quarters, then your net surplus is increased from one hundred to one hundred and fifty quarters; and consequently, either the farmer's profit or the landlord's rent increased in a corresponding proportion. There are many tracts of land which cannot now be cultivated, because the quantity of produce expended in cultivation and in carriage exceeds the quantity which that expenditure would bring to market. But if you diminish the quantity expended in bringing a given quantity to market, then you may obtain a nett surplus produce from such inferior soils, and consequently allow cultivation to be extended over tracts which could not otherwise be tilled. On the same principle, lowering the expense of carriage would enable you to apply additional quantities of labor and capital to all the soils already under cultivation. But it is not necessary to go into any illustrative examples to explain this, it being a well known principle, that every improvement which allows us to cultivate land of a quality which could not previously be cultivated, also enables us to cultivate, in a higher manner, lands already under tillage.

If horses were displaced from common roads, would not the demand for oats, beans, and for pasture, be diminished, and land thereby be thrown out of cultivation, and labor out of employment? If steam carriages were very suddenly brought into use, and horses thereby displaced, I think the effect stated in the question would be produced for a time; but, practically, steam carriages can be introduced only very gradually, and the beneficial effect

upon the profits of trade, by bringing agricultural produce more cheaply to market, will tend to increase profits, to encourage industry, and to enlarge the demand for labor; so that by this gradual process there will probably be no period during which any land can actually be thrown out of cultivation, the increasing population requiring all the food which horses would cease to consume. With respect to demand for labor, that demand consists of the quantity of food and raw materials which can be cheaply obtained; and as, by the supposition, the displacing of horses will leave at liberty more food and more material, the demand for labor will ultimately be greatly increased instead of being diminished. It has been supposed, I know not how accurately, that there are employed on the common roads in Great Britain, one million of horses, and a horse, it is calculated, consumes the food of eight men. If steam carriages could ultimately be brought to such perfection as entirely to supersede draught horses on the common roads, there would be food and demand for eight millions of persons. But when we take further into consideration, that, lowering the expense of carriage would enable us to extend cultivation over soils which cannot now be profitably tilled, and would have the further effect of enabling us to apply, with a profit, additional portions of labor and capital to the soils already under tillage, I think it not unfair to conclude, that, were elementary power on the common roads completely to supersede draught horses, the population, wealth and power of Great Britain would at least be doubled.

There are soils which are stated to be so poor, that oats alone can be raised upon them—would not the substitution of steam for horse power have the effect of throwing out of employment the labor required for the cultivation of such lands? If there are soils of such a peculiar quality that oats is the only marketable product which they will yield, the persons employed in cultivating those lands would certainly be thrown out of that particular occupation; but the extension of tillage over other lands not of this peculiar quality, would create a demand for labor which would much more than absorb the persons thrown out from the culture of oats upon that land which would grow nothing else. But I doubt of there being any land which it is profitable to cultivate, which would not raise some other agricultural produce than oats either for man or cattle, for which the increasing population would create a demand.

The general impression on the minds of the committee is, that steam carriages will, at least for the present, rather be substituted for horses used in conveying travellers, than for the conveyance of bulky articles. Do you think that the substitution of steam in this manner will be injurious to agriculture, and to the demand for labor without any adequate compensating advantages? Upon the case supposed, namely, that steam carriages should be employed in conveying passengers only, and the whole change to be affected in a sudden manner, I think that there would, in the first instance, be a diminished demand for agricultural produce, but the following process would take place. As the demand for agricultural produce was diminished, the price of such produce would fall, food would become cheaper, and the cheapening of food would benefit partly the laboring class and partly the capitalist—the one obtaining higher real wages, and the other higher profits; this increase in real wages and profits, would effect a great encouragement to manufacturing industry, and would necessarily lead to an increase in the manufacturing population, and to the amount of capital employed in manufactures. The consequence would be, that, after some degree of pressure upon agriculture, the increased number of human beings would create the same demand

for agricultural produce which the employment of horses formerly created. So that even upon the extreme and most improbable supposition that steam carriages should never be employed in conveying agricultural produce to market at a cheaper rate, still the benefit to the country would be very great, inasmuch as we should have a vastly increased industrious population, and England would become much more extensively, than she is at present, the great workshop of the world. In point of fact, superseding horses by mechanical power, would have precisely the same effect in increasing the population and wealth of England as would be produced were we to increase the extent of the country by adding thereto a new and fertile territory, equal in extent to all the land which now breeds and feeds all the horses employed upon common roads. Such addition to the extent of fertile territory in England, suddenly affected, would, in the first instance, lower the value of agricultural produce, and be injurious to the proprietors of the old portion of the territory, but no person would, therefore, contend that if we could enlarge the island of Great Britian by additional tracts of fertile land, the public interests would be injured by such enlargement: this would be monstrously absurd. It is not less absurd to object to the increase of food available for human beings, by substituting mechanical power for horses.

In addition to the advantages you have already anticipated from the introduction of steam conveyance, would not the increased speed and cheapness of intercourse occasion vast public benefits in which agricultural capitalists and laborers must greatly partake? Certainly.

As it is impossible to conceive that steam should be generally substituted for horses, and be confined only to the conveyance of travellers, and, as it would necessarily be employed as vans and coaches are at present, for the speedy conveyance of light goods as well as travellers, (by the hypothesis steam carriages being cheaper than horse draft, or it would not be used,) would not such cheapening of the conveyance of such goods have a considerable effect upon the demand for them, and thereby for labor and food? On the principles that have been already stated with respect to agriculture, the cost of bringing all things to market is comprised of the cost of production and the cost of carriage. Reducing the cost of carriage is precisely the same thing in its effects as reducing the immediate cost of production, consequently the conveyance of light goods by steam power must cheapen all such goods to the consumers. This will necessarily enable them to consume a greater quantity of such goods, and the consumption of the greater quantity will enlarge the demand for labor, call a larger manufacturing population into existence, and thereby re-act on agriculture by increasing the demand for food. This cheaper mode of internal carriage will not only lower the price of light and refined manufactures to the home consumer, but will lower their price also to the foreign consumer. This will increase the advantages which we at present possess in the foreign market, and tend to increase our foreign commerce. So that here again there will be an increased demand for manufactures and for a manufacturing population, and here again will be another beneficial re-action upon the soil. So that the more we contemplate the various effects produced upon the industry of the country by a cheaper mode of conveyance, the more we must be convinced that wealth and population will be increased, and that agriculture, instead of being injured, must necessarily partake in the increased prosperity of the country. In addition to what I have already stated, the saving of expense and of time in conveying passengers and goods, and the rapidity of communication, will produce effects, the amount of which it would be almost impossible to calculate.

APPENDIX.

APPENDIX A.

Answers to queries submitted by the committee to Mr. John Macneill.

Query 1. What is the greatest weight, in proportion to its own weight, which any locomotive steam engine has been found capable of drawing upon a railroad, and at what velocity?

In the first edition of Mr. Nicholas Wood's Treatise on Railroads, published in 1825, he states that a locomotive engine, weighing 6½ tons, and containing one ton of water, equal to 7½ tons, dragged twelve loaded carriages, each weighing 9,408lbs., up a plane ascending 134 inches in 1,164 feet, and also the conveying carriage, weighing 1½ tons, the wheels not slipping, the rails dry.

He also gives the following experiments made on the Killingworth railroad: The length of plane was 2,260 yards, with an ascent in one direction of 6 feet 5 inches, not uniform, varying from a dead level, or slightly undulating, to an ascent in one place of 1 in 330. Edge rail, 2½ inches broad on the surface; carriages all the same construction, weighing 81¼ cwt. each, wheels 34 inches diameter, axles 2¾ inches diameter.

Experiment 29.

Wheels, three feet; nine carriages, weighing 731¼ cwt., were drawn up the plane fourteen times in 317 minutes, and fourteen times down the plane in 258 minutes; distance traversed, 36 miles in 9 hours 35 minutes; coals consumed, 2,534 lbs.; water, 890 gallons.

Experiment 30.

Wheels, four feet; nine carriages, weighing 731¼ cwt., were drawn up the same plane nineteen times in 302 minutes, and nineteen times down the plane in 265 minutes; distance traversed, 48.8 miles in 9 hours 27 minutes: coals consumed, 2,534 lbs.; water, 854 gallons.

Experiment 31.

Wheels, four feet; twelve carriages, weighing 975 cwt., were drawn up the plane nine times in 155 minutes, and nine times down in 133 minutes. Distance traversed, 23 miles in 4 hours 48 minutes; coals consumed, 1,546 lbs.; water, 452 gallons.

Experiment 32.—(*With a different locomotive engine.*)

Wheels, three feet; nine carriages, weighing 731¼ cwt., were drawn up the same plane ten miles in 212 minutes, and ten times down in 180 minutes. Distance, 26 miles; time, 6 hours 32 minutes; coals consumed, 1,487 lbs.; water, 490 gallons.

Experiment 33.

Wheels, four feet; twelve carriages, weighing 975 cwt., were drawn up the plane five times in 45 minutes 48 seconds, and five times down, in 40 minutes 26 seconds. Distance each journey, 2,002 yards. Total, 11.375 miles; distance passed over in the above time 1,663 yards each journey, or 9.45 miles; time, 1 hour 26 minutes 14 seconds; coals consumed, 587 lbs.; water, 200 gallons.

In this experiment, the engine was allowed to traverse a given space, to put the train of carriages into their proper velocity before the time was noted; the time was then marked until the velocity was again checked at the farther end of the stage. This will explain the difference between the two distances stated in the experiment: the one was the whole distance, from the commencement to the end of the stage; the other was that part of the stage which the engine passed over when the regular velocity was acquired, and before it was again diminished at the end of the stage, to stop the train; the time given, was that which transpired while the engine was passing over that space, while the velocity was uniform, and may therefore be taken as a measure of speed.

At page 281, Mr. Wood states: Upon a railroad near Newcastle, a locomotive engine, in fifty-four weeks, conveyed 53,823 carriages of coals, each weighing 9,438 lbs., 2,541 yards, and returned with the same number of empty carriages, each weighing 3,472 lbs. This was in fifty-four successive weeks; and, in that time, exclusive of Sundays, the engine, from want of goods to convey, was at least twenty days off work; so that in 304 days, the performance was 446,815 tons conveyed one mile; or 1,470 tons one mile each day, on a stage only 2,541 yards. The engine had three feet wheels, which were calculated for a rate of about 4½ miles per hour.

Mr. Rastrick, in his report to the directors of the Liverpool and Manchester railway, dated January, 1829, gives the following table of the absolute quantity of work done by five different locomotive engines, when reduced all to the same standard of five, eight, and ten miles per hour. The carriages proportioned to the weight of goods, in the same ratio as they were proposed for the Liverpool and Manchester railway, and also of the work that the ten-horse engine, proposed by him and Mr. Walker, would be capable of doing:

TABLE.

ENGINES.	RAILROADS.	IN SUMMER.											
		At five miles per hour.				At eight miles per hour.				At ten miles per hour.			
		Goods.	Carriages.	Engine and tender.	Gross weight.	Goods.	Carriages.	Engine and tender.	Gross weight.	Goods.	Carriages.	Engine and tender.	Gross w'ght
		Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Engine on six 4 feet wheels, (Hackworth.)	Stockton and Darlington,	47¾	23¾	15	86½	26	18	15	54	18¾	9½	15	43¼
Engine on four 4 feet wheels,	Stockton and Darlington,	34⅔	17⅓	12	64	18⅔	9⅛	12	40	13⅓	6⅔	12	32
Engine on four 4 feet 2 in. wheels,	Killingworth Colliery,	38	19	10½	67½	21	10½	10½	42	15½	7¾	10½	33¾
Engine on four 3 feet wheels,	Hetton Colliery,	24¼	12	10½	46¾	12½	6¼	10½	29¼	8⅔	4⅓	10½	23½
Engine on four wheels, rack rail,	Middleton Colliery near Leeds,	22¼	11	6¼	39½	12¼	6¼	6¼	24¾	9	4½	6¼	19¾

TABLE—Continued.

ENGINES.	RAILROADS.	IN WINTER.											
		At five miles per hour.				At eight miles per hour.				At ten miles per hour.			
		Goods.	Car-riages.	Engine and tender.	Gross w'ght	Goods.	Car-riages.	Engine and tender.	Gross weight.	Goods.	Car-riages.	Engine and tender.	Gross weight.
		Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Engine on six 4 feet wheels, (Hackworth.)	Stockton and Darlington,	$40\frac{3}{4}$	$20\frac{1}{4}$	15	76	$21\frac{3}{4}$	$10\frac{3}{4}$	15	$47\frac{3}{4}$	$15\frac{1}{4}$	$7\frac{3}{4}$	15	38
Engine on four 4 feet wheels,	Stockton and Darlington,	$28\frac{3}{4}$	$14\frac{1}{2}$	12	$55\frac{1}{4}$	15	$7\frac{1}{2}$	12	$34\frac{1}{2}$	$10\frac{4}{10}$	$5\frac{3}{10}$	12	$27\frac{6}{10}$
Engine on four 4 feet 2 in. wheels,	Killingworth Colliery,	$31\frac{1}{4}$	$15\frac{3}{4}$	$10\frac{1}{2}$	$57\frac{1}{2}$	17	$8\frac{1}{2}$	$10\frac{1}{2}$	36	12	$6\frac{1}{2}$	$10\frac{1}{2}$	$28\frac{3}{4}$
Engine on four 3 feet wheels,	Hetton Colliery,	$19\frac{3}{4}$	$9\frac{3}{4}$	$10\frac{1}{2}$	40	$9\frac{3}{4}$	$4\frac{3}{4}$	$10\frac{1}{2}$	25	$6\frac{1}{4}$	$3\frac{1}{4}$	$10\frac{1}{2}$	20
Engine on four wheels, rack rail,	Middleton Colliery near Leeds,	$19\frac{1}{4}$	$9\frac{1}{2}$	$6\frac{1}{4}$	35	$10\frac{1}{4}$	$5\frac{1}{4}$	$6\frac{1}{4}$	$21\frac{3}{4}$	$7\frac{1}{2}$	$3\frac{3}{4}$	$6\frac{1}{4}$	$17\frac{1}{2}$

The engines started for the premium of £500, on the *Liverpool* and *Manchester* railway, in October, 1829, were the *Rocket*, *Novelty*, and *Sans Pareil.*

The *Rocket* weighed - -	4	5	–	–	--Full speed, 30 miles in 2h. 14m. 8s., equal to $13\frac{4}{10}$ per hour; back, 30 miles, in 2h. 6m. 9s.; equal to $14\frac{2}{10}$ per hour.
tender, with water and coke	3	4	–	2	
two carriages, loaded -	9	10	3	26	
	17	–	–	–	

Sans Pareil—weight of engine	4	15	2	–	--Full speed, $10\frac{1}{2}$ miles in 50m. 49s. equal to $12\frac{4}{10}$ per hour; back, 12 miles in 40m. 27s.; equal to $15\frac{5}{10}$ per hour.
tender, with water and fuel	3	6	3	–	
three carriages - -	10	19	3	–	
	19	2	–	–	

Novelty—weight of engine with water in the boiler	3	1	–	–	--Total time, 22m. 57s.; and distance run, $4\frac{1}{2}$ miles.
tank, water and fuel - -	–	16	–	14	
two carriages, - -	6	17	–	–	
	10	14	–	14	

N. B.—The railway was level, and about two miles in length, where the experiments were made.

QUERY 2. What may be considered as the greatest performance of locomotive carriages previous to the Manchester and Liverpool railway being opened?

Mr. Wood, in 1825, states, that the performance of the best locomotive engine was equal to 40 tons, conveyed at the rate of six miles an hour; and four years after, (in 1829,) Messrs. Rastrick and Walker have stated that $48\frac{1}{2}$ tons, conveyed five miles an hour, or $19\frac{1}{2}$ tons conveyed ten miles an hour, was the greatest performance the directors of the Liverpool railway could expect from them.

I have seen some statements of experiments in which the effective work was greater than the above; but I am inclined to think they could not be so well depended on as those of Messrs. Wood, Rastrick, and Walker.

QUERY 3. What has been the greatest performance of any engine since that period?

On the 23d of February, 1831, Mr. Robert Stephenson stated to the Society of Civil Engineers, that the Northumbrian locomotive engine, weighing 6 tons 3 cwt., drew 50 tons up the inclined plane at Rainhill, at the average rate of $7\frac{1}{2}$ miles per hour: pressure of steam was 50 lbs. on the square inch. The inclination of the ground at Rainhill is 1 in 96.

On the 1st of March, 1831, Mr. Locke stated that "the Samson" drew a gross weight of 151 tons, in 30 wagons, (the nett weight being 107 tons,) the whole distance from Liverpool to Manchester, in 2 hours 34 minutes, including 13 minutes of stoppages. The diameter of the wheels was 4 feet 6 inches.

On the 19th of April, 1831, Mr. Locke stated, that "the Samson" drew up the inclined plane at Rainhill, about 44½ tons, gross, of goods and wagons, at the rate of about eight miles an hour.

Weight of the engine was 8½ tons; weight of tender, (which was full of water,) 4 tons; making the total weight of goods, wagons, engine, and tender, 57 tons; and, calculating the speed of the engine eight miles per hour, she was exerting a force equal to 39 horse power.

He also stated that a new engine, "the Jupiter," had just been started. From the 4th of March to 6th of April, she drew 226 wagons (only ten of which were empty,) and 847 coaches, a total distance of 3,426 miles. In one fortnight she made fifty journies, equal to 1,500 miles.

Diameter of cylinder, 11 inches; length of stroke, 16 inches; diameter of the wheels, 5 feet. Value of such an engine, £700.

APPENDIX B.

Proposed scale for turnpike tolls on steam carriages.

Every carriage propelled by steam, or other elementary power, carrying only fuel and engineers, and having the tires of the wheels less than two inches and a half, and,				But if the carriage draws or propels another,	
Weighing Cwt. 5	and not exc'ding Cwt. 10	a toll as	One horse *not drawing*	then as	One horse *drawing*
10	20	-	Two - -	-	Two -
20	30	-	Three - -	-	Three -
30	40	-	Four - -	-	Four -
40	50	-	Five - -	-	Five -
50	60	-	Six - -	-	Six -

Above this weight an arbitrary toll, preventing its exceeding it on narrow wheels.

If the tires of the wheels exceed three inches, the tolls should be about one quarter less; and the weight, without injury, may extend to three tons and a half. If the tires of the wheels are six inches wide, the tolls should be about a third less, and the weight allowed to extend as far as four or five tons.

APPENDIX C.

RETURN of all turnpike road bills which passed the House of Commons in session 1830–31, wherein any toll has been imposed on carriages propelled by steam, or other mechanical contrivance, distinguishing the amount of toll charged per horse on stage carriages, vans, wagons, and cars, and the charge on steam carriages.

	Stage coaches, &c. per horse.	Wagons, vans, &c. according to the breadth of the wheels per horse.	Propelled by machinery.	
			Carriages with two wheels.	Carriages with four wheels.
Bedfont road -	6d.	4d. 5d. 6d.	6d. per wheel for all carriages.	
Highgate and Whetstone road -	6d.	4d. 5d. 6d.	1s. 6d.	2s. 6d.
Norwich and Yarmouth road - -	6d.	4d. 6d.	2s. for all carriages.	
Walsall roads -	4½d.	4½d. 6d. 8d.	2s.6d. for all carriages.	
Stretford road -	6d.	6d. 7½d. 9d.	The same toll as if drawn by 4 horses.	
Tunbridge Wells, and Maresfield road	4d.	2d. 3d. 4½d.	1s. per ton weight for all carriages.	
Birmingham & Bromsgrove road	4½d.	2½d. 3d. 4½d.	For locomotive engines drawing carriages, 2s.; for steam carriages for passengers, &c., 1s. 6d.	
Perry Bar and Handsworth road -	4½d.	4½d. 6d. 8d.	2s. 6d. for all carriages.	
Enfield Chase road -	4d.	3d. 4½d. 6d.	1s. for all carriages.	
Lemsford Mill road -	7½d.	6d.	1s. 6d.	2s. 6d.
Linlithgowshire roads	For 1 horse, 1s. 6d.; two horses, 2s.; 3 or 4 ditto, 4s.	For 1 horse, 6d. 2 do. 10d. 3 do. 3s. 4 do. 4s. 5 do. 6s. 6 do. 8s.	One penny per cwt. for all carriages.	
Coventry, and Over Whiteacre road -	3d.	2d. 3d. 4d.	2s. 6d. for all carriages.	
Watling Street road -	4½d.	4d. 5d. 6d.	2s. 6d. for all carriages.	
Pinwall Lane road -	4½d.	4d. 5d. 6d.	2s. 6d. for all carriages.	
Worthing and Littlehampton road	6d.	4d. 5d. 6d.	1s. per wheel for all carriages.	
Leeds and Birstal road	8d.	6d. 7½d. 9d.	2s. per wheel for all carriages.	
Haslemere road -	4½d.	4½d.	1s.	2s.
Macclesfield & Nether Tabley road	6d.	6d. 8d.	9d. per wheel for all carriages.	
Glamorganshire roads	6d.	6d.	1s. 6d.	3s.
Cleeve and Evesham road - -	9d.	9d.	1s. 6d.	3s.
Pucklechurch roads -	6d.	6d. 7½d. 9d.	1s. per cwt.	
Leicester and Welford road - -	4½d.	3d. 3½d. 4d.	1s. for all carriages.	
Lampeter roads -	6d.	4½d. 5½d. 6d.	The same toll as if drawn by 4 horses.	
Llandovery and Llangadock road	6d.	4½d. 5½d. 6d.	The same toll as if drawn by 4 horses.	

APPENDIX C—Continued.

	Stage coaches, &c. per horse.	Wagons, vans, &c. according to the breadth of the wheels per horse.	Propelled by machinery.	
			Carriages with two wheels	Carriages with four wheels.
Bathgate roads	1s. 3d.	For 1 horse, 9d. if more than 1, 6d. per horse.	2s. 9d. for all carriages not exceeding 25 cwt.	
Titchfield & Cosham road	6d.	3d. $3\frac{3}{4}$d. $4\frac{1}{2}$d.	2s. per wheel for all carriages.	
Cheadle roads	6d.	4d. 5d. 9d.	5s. for all carriages.	
Bruton roads	6d.	$4\frac{1}{2}$d. 6d. $7\frac{1}{2}$d. 9d.	4s. for all carriages.	
Coventry and Stony Stanton road	3d.	4d. 5d. 6d.	2s.6d. for all carriages.	
Liverpool and Preston road	6d.	If drawn by 4 or 5 horses, 1s., 1s. 5d., 2s. 3d., 2s. 5d. If by 2 or 3 horses, 4d., 6d., 8d.	If not exceeding one ton, 6d. per wheel; and 6d. per wheel for every further ton weight.	

APPENDIX D.

RETURN of all private bills which have passed the House of Commons, wherein any toll has been imposed on carriages propelled by steam or other mechanical contrivance, distinguishing the amount of toll charged per horse on stage carriages, vans, wagons, and cars, and the charge on steam carriages.

	Stage coaches, &c. per horse.	Wagons, vans, &c. according to the breadth of the wheels.	Propelled by machinery.	
			Carriages with three, or a less number of wheels.	Carriages with four or more wheels.
Kidwelly roads	6d.	4d. 5d. 6d.	2s. for two-wheeled carriages - -	3s.
Lynn (east gate) road	4d.	3d. $3\frac{3}{4}$d. $4\frac{1}{2}$d.	2s.6d. for all carriages.	
Lynn (south gate) road	4d.	3d. $3\frac{1}{4}$d. $4\frac{1}{2}$d.	2s. 6d. for all carriages.	
Handsworth road	6d.	6d. 8d. 9d.	The same toll as if drawn by 4 horses.	
Aylsham road	3d.	2d.	9d.	1s. 6d.
Cheltenham roads	8d.	- -	3s. for all carriages.	
Liverpool and Prescot road	1s. 6d. and 1s.	6d. 8d. 10d. 1s.	1s. 6d. for every horse-power for all carriages.	
Abergavenny roads	6d.	8d. 9d. 1s.	The same toll as if drawn by four horses.	

APPENDIX D—Continued.

	Stage coaches, &c. per horse.	Wagons, vans, &c. according to the breadth of the wheels.	Propelled by machinery. Carriages with three, or a less number of wheels.	Propelled by machinery. Carriages with four or more wheels.
Drogheda roads -	6d.	2d. 4d. 6d. 1s.	The same toll as if drawn by two horses.	
St. Alban's road -	6d.	- -	1s. 6d.	2s. 6d.
Sunderland roads -	4½d.	3d. 4d. 9d. 1s.	6d. for every horse power for all carriages.	
Wisbech and Thorney road - -	6d.	3d. 3¾d. 4½d.	2s.	4s.
Frome roads -	6d.	6d. 7d. 8d.	2s. for all carriages.	
Huddersfield & Woodhead road -	6d.	3d. 4d. 4½d.	2s. 6d. for all carriages.	
Wakefield and Austerlands road -	6d.	4d. 5d. 6d.	2s. 6d. for all carriages.	
Monmouth roads -	8d.	5d. 6d. 7d. 1s.	1s. 6d.	2s. 6d.
Wakefield Ings road -	3d.	1d. 1½d. 2d.	6d.	1s.
Stirlingshire roads -	1s. 3d.	If not exceeding 25 cwt., 9d.; if between 25 and 30 cwt. 1d. in addition, and so in proportion.	2s. 6d. for every carriage not exceeding 25 cwt.; if between 25 and 30 cwt. 1d. per cwt. in addition, and so in proportion.	
Exeter roads - -	8d. 9d.	If drawn by one horse only, 9d.; if by two or more horses, 6d. per horse.	If not exceeding one ton, 6d. per wheel; if more than one ton, 6d. per wheel in addition, and 6d. per wheel for every further ton weight.	
Teignmouth & Dawlish road	If drawn by 2 or 3 horses, 8d.; if by 4 or more horses, 6d.	9d.	If not exceeding one ton, 6d. per wheel; if more than one ton, 6d. per wheel in addition, and 6d. per wheel for every further ton weight.	
Darlington road -	If drawn by 2 or 1 horse, 10d.; if by 4 horses, 8d. and if by 6 horses, 6d. per horse.	6d. 8d. 10d.	1s.	2s.

Private Bill Office,

House of Commons, August 22, 1831.

EDW. JOHNSON.

APPENDIX E.

SCALE for fixing Tolls on the various kinds of Steam Carriages equivalent to Horse Coaches, calculated on the comparative wear and tear of roads.

[Given in to the Committee by Mr. GURNEY.]

The following Scale of Proportions is taken from a trust where the tolls fixed are three pence for every horse *drawing*, and one penny *not drawing*; and may be applied to determine the tolls on any other trust, where the tolls are fixed at a higher or lower rate.

Every Steam Carriage with the tires of the wheels under two inches and a half, and				Every Steam Carriage with the tires of the wheels not less than four inches, and				Every Steam Carriage with the tires of the wheels not less than six inches, and			
Weighing	But not exceeding	Shall pay a toll, when drawing one carriage only, of	Not drawing any carriage	Weighing	But not exceeding	Shall pay a toll, when drawing one carriage only, of	Not drawing	Weighing	But not exceeding	Shall pay a toll, when drawing one carriage only, of	Not drawing
Cwt.	*Cwt.*	*s. d.*	*d.*	*Cwt.*	*Cwt.*	*s. d.*	*d.*	*Cwt.*	*Cwt.*	*s. d.*	*d.*
5	10	0 3	1	10	20	0 4	1	20	30	0 3	1
10	20	0 6	2	20	30	0 6	1½	30	40	0 5	1½
20	30	0 9	3	30	40	0 8	2	40	50	0 7	2
30	40	1 0	4	40	50	0 10	3	50	60	0 9	2½
40	50	1 3	5	50	60	1 0	4	60	70	0 11	3
50	60	1 6	6	60	70	1 2	4½	70	80	1 1	3½
above 60	for every extra 100 wt.	0 3	1	above 70	for every extra 100 wt.	0 2	¾	above 80	for every extra 100 wt.	0 1½	½

N. B.—The carriage and load drawn by the steam carriage, shall not exceed double the weight of the drawing carriage.

APPENDIX F.

EXTRACTS from Seventh Report of the Holyhead Road Commissioners, showing the number of lbs. required to draw a wagon of the weight of 21 cwt. 8 lbs. at the rate of 2½ miles per hour.

Parts on which the experiments were tried.	Number of observations.	Rate of inclination.	Actual draught in lbs., or proportional number of horses required on each station.	Correction for the rate of inclination.	Draught reduced, or the proportional number of horses that would be required if the road was horizontal.	OBSERVATIONS. All the experiments were made in the middle of the month of March, 1830, during dry weather.
No. 1.—Piccadilly Pavement:						
From Stratton-street to Devonshire House	15	Rise, 1 in 114	60½	20½	40	Excellent, smooth, well laid pavement.
Devonshire House to Dover-street -	14	Rise, 1 in 156	48¼	15¼	33	Ditto ditto.
Dover-street to James-street - -	13	Fall, 1 in 429	42¼	5¾	48	Pavement uneven and worked into holes, the top of the stones a good deal rounded, and the joints opened.
St. James-street to Bond-street - -	8	Rise, 1 in 245	54	9	45	
Bond-street to Burlington Arcade -	11	Fall, 1 in 286	40	8¼	48¼	
Burlington Arcade to Albany-court -	20	Horizontal -	41¾	-	41¾	
No. 2.—Archway Road:						
Between toll-bar and new house on the right	32	Rise, 1 in 23	173	102½	70½	This road lately repaired by putting on a cemented foundation, and covering the fifteen middle feet with broken Guernsey granite, six inches in thickness.
Between new house and Depot No. 1 -	13	Rise, 1 in 23	163	102½	60½	
Between Depot No. 1, and Archway -	64	Rise, 1 in 22	171	108	63	
Between Archway and lamp No. 11 -	31	Rise, 1 in 49	115	48	67	
Between eleventh and twelfth lamp posts -	13	Rise, 1 in 229	78	10¼	67¾	
Between twelfth and thirteenth lamp posts	12	Horizontal -	47	-	47	
Between thirteenth and fifteenth lamp posts	26	Fall, 1 in 382	46	6¼	52¼	
Between nineteenth and twenty-first lamp posts	35	Rise, 1 in 27	151	87	64	
Between twenty-first and twenty-second lamp posts	22	Rise, 1 in 27	152	87	65	The surface not perfectly consolidated, and shaded with trees.
Between twenty-second lamp post and M'Pherson's	16	Rise, 1 in 3,437	59	½	58½	
Between Wellington inn and Whetstone-road	20	Horizontal -	44	-	44	On this portion Hartshill was used instead of granite.

APPENDIX F--Continued.

Parts on which the experiments were tried.	Number of observations.	Rate of inclination.	Actual draught in lbs., or proportional number of horses required on each station.	Correction for the rate of inclination.	Draught reduced, or the proportional number of horses that would be required if the road was horizontal.	OBSERVATIONS. All the experiments were made in the middle of the month of March, 1830, during dry weather.
No. 3.—HOCKLIFFE AND STRATFORD TRUST:						
Near Fountain inn, Shenley - -	49	Horizontal -	97	-	97	12 inches of limestone; low fences.
Near Talbot inn, north of Shenely -	36	Rise, 1 in 20½	232	115	117	Ditto good foundation, firm and dry, not worked in.
Flat, north side of Shenley - -	34	Fall, 1 in 119	93	19¾	112¾	12 inches limestone; plantation south side.
Ditto, near Speckland Hollow - -	77	Horizontal -	120	-	120	11 inches pebble and limestone; plantation south side.
Crown Hill - - - -	38	Rise, 1 in 45	128	52½	75½	} Embankment; paved foundation, coverd with 10 inches of broken limestone.
Ditto, near summit - -	26	Rise, 1 in 27	136	87	49	
Between Crown Hill and the tollbar -	56	Rise, 1 in 66	115	35¾	79¼	12 inches limestone; no sub-pavement.
Flat between Two-mile Ash and Stony Stratford	68	Rise, 1 in 3,437	60	1	59	18 inches limestone; low fences, no trees.
Near same place, tried back - -	58	Fall, 1 in 3,437	57	1	58	Ditto ditto.
No. 4.—STRATFORD AND DUNCHURCH TRUST:						
Flat between 65th mile-stone and brick house	23	Rise, 1 in 20	270	118	152	6 inches limestone; low fences each side; trees and high bank on west.
Between brick house and road to Northampton	7	Rise, 1 in 21	292	112	180	5½ inches limestone; high hedges, and bank on south-west.
Over small embankment above brick house	22	Rise, 1 in 22¾	343	103	240	6 inches limestone, high hedges, new stone, on a week.
Between sand pits and road to Stowe -	23	Rise, 1 in 39	128	60½	67½	6 inches limestone; open and low fences.
Between road to Stowe and the Angel inn	37	Rise, 1 in 71½	95	33	62	5 inches limestone; open wide space between, low fences.
Between hollow and 66th mile-stone -	70	Rise, 1 in 31	130	76	54	3½ inches of Hartshill, and 2 inches of limestone, on pitching.
Between 66th mile-stone and summit of hill	80	Rise, 1 in 26	145	91	54	3 inches ditto ditto over embankment.
Rising next hill - - - -	60	Rise, 1 in 50	90	47	43	5 inches ditto ditto through cutting.

Extract from Mr. Telford's Report on the state of the Holyhead and Liverpool Roads.

Being authorized by the commissioners to have the machine invented by my assistant, Mr. Macneill, (for measuring the force of traction, or the labor of horses in drawing carriages,) completed, and also to have the several districts of the Holyhead road in England tried by it, Mr. Macneill has done so, and prepared a statement showing the results of the trials between London and Shrewsbury, a distance of 153¼ miles.

The general results of these experiments* on different sorts of roads, are as follows:

1. On well made pavement, the draught is - - - 33 lbs.
2. On a broken stone surface on old flint road - - - 65
3. On a gravel road - - - - - - 147
4. On a broken stone road, upon a rough pavement foundation 46
5. On a broken stone surface upon a bottoming of concrete, formed of Parker's cement and gravel - - - 46

The general results of experiments made with a stage coach,† on the same piece of road, on different inclinations, and at different rates of velocity, are given, from which the following statement has been calculated:

Rate of inclination.	Rates of travelling.	Force required.
1 in 20	6 miles per hour	268 lbs.
1 in 26	6 " -	213
1 in 30	6 " -	165
1 in 40	6 " -	160
1 in 600	6 " -	111
1 in 20	8 " -	296
1 in 26	8 " -	219
1 in 30	8 " -	196
1 in 40	8 " -	166
1 in 600	8 " -	120
1 in 20	10 " -	318
1 in 26	10 " -	225
1 in 30	10 " -	200
1 in 40	10 " -	172
1 in 600	10 " -	128

Having the results of these accurate trials to refer to, leaves it no longer a matter of conjecture in what manner a road should be made to accomplish, most effectually, the main object, that is, diminishing, to the greatest possible degree, the labor of horses in draught.

* In making these experiments, a wagon, weighing about 21 cwt. was used.
† Weight of coach, exclusive of seven passengers, 18 cwt.

Although the observations of scientific persons have led to nearly similar conclusions, others have been in the habit of laying down rules for road-making at variance with all the established laws of motion; it is satisfactory to be able to produce a positive proof by actual experiment, of their opinions being wholly erroneous.

In this view, I consider Mr. Macneill's invention, for practical purposes on a large scale, one of the most valuable that has been lately given to the public.

DOCUMENTS

IN RELATION TO

THE COMPARATIVE MERITS OF CANALS AND RAILROADS,

SUBMITTED BY

MR. HOWARD, OF MARYLAND,

AND APPENDED BY ORDER OF THE COMMITTEE ON INTERNAL IMPROVEMENTS
OF THE HOUSE OF REPRESENTATIVES.

DOCUMENTS

RELATIVE TO

The comparative merits of Canals and Railroads, submitted by Mr. Howard, of Maryland.

ENGINEER'S OFFICE, BALTIMORE AND OHIO RAILROAD,
Baltimore, March 5, 1832.

TO PHILIP E. THOMAS, *President, &c.*

In accordance with thy request, I have read document No. 18, of the House of Representatives, 1st session 22d Congress, and now submit the following report and accompanying documents on the subject of the relative advantages of railroads and canals.

It is regretted that more time could not be allowed for the compiling of statements and explanations with regard to the relative merits of canals and railways. As it is, what can now be presented will be very limited and brief, and much short of that which, it is conceived, the subject demands, and far less of that of which it admits. We shall begin with the following comparison of canals, railways, and turnpike roads, with regard to the effects of the moving power upon them.

In document No. 18, (before mentioned,) page 190, after quoting from N. Wood's Treatise on Railroads, ed. 1825, and from Tredgold's Treatise of the same date, is the following paragraph, to wit:

"It is proper to remark, that from Tredgold, as from other English treatises on railroads, passages may be extracted less favorable than the preceding to the superiority of canals: but enough is here quoted to show the uncertainty which hung over the question—whether canals or railroads were to be preferred for the transportation of persons and property. No two authors, scarcely, will be found to concur, precisely, in opinion on the subject; nor the same author with himself."

In the first place, we may here remark, that the disagreement of authors with each other, or with themselves, cannot be received as good evidence against improvements either in mechanics or in modes of conveyance, any more than difference of opinion, opposition, or even apparent inconsistency, in the members of a legislative body, would be valid evidence against bills or amendments: for, otherwise, improvements in the one case, and amendments in the other, would be indefinitely postponed. The truth, however, is, that public opinion will always be founded upon the facts, as they shall be, from time to time, developed and shown to exist, with regard to all improvements; and public opinion will seldom err. Turnpike roads, canals, the steam engine, and steamboats, have each, in turn, in spite of powerful opposition, received the sanction of public opinion. Railroads are now upon the stage, and are being subjected to the same great and discriminating ordeal; and when we reflect upon the magnificent results which their success, coupled with the application of steam, upon them, will produce, we

can neither wonder that their introduction should be opposed, nor doubt of their triumph.

The author of the document, whose object would appear mainly to have been to determine Congress and the public in favor of the canal, and against the railroad, *here acknowledges* that passages more favorable to the railroad system exist in the works of those authors.

Now, what are the facts? The compiler of document No. 18 has quoted from English works seven years old. Seven years is a long period, when measured by the time elapsed since the application of railways to the purposes of general conveyance Within this period, very great improvements have been effected, not only in the formation of railways, but in the application to them of machinery, and motive power.

These improvements have been such as to double or treble the useful effects, and even to *quadruple* the attainable velocity which had previously been had upon railways. The *relative* friction, or *traction*, upon level railways, in the year 1825, was set down by Tredgold at the $\frac{1}{144}$th part of the weight moved, and his table V.,* copied on page 189, document No. 18, was calculated accordingly; whilst Wood, in his treatise of the same date, (1825,) expressed his opinion, derived from experiments, to be, that the traction may be taken at the $\frac{1}{200}$th.

Since that time, however, the common railway car, in England, has undergone improvements, and the friction is stated, in the second edition of Nicholas Wood's Treatise on Railroads, London, 1831, to be the $\frac{1}{240}$th of the weight. In this country, and on the Baltimore and Ohio railroad, seve-

* The following is the table, as given in Doc. 18.

A TABLE showing the effects of a power or force of traction of one hundred pounds, at different velocities, on Canals, Railroads, and Turnpike Roads.

Velocity of motion.		Load moved by a power of 100 lbs.					
		On a Canal.		On a level Railway.		On a level Turnpike road.	
Miles per hour.	Feet per second.	Total mass moved.	Useful effect.	Total mass moved.	Useful effect.	Total mass moved.	Useful effect.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2½	3 66	55,500	39,400	14 400	10,800	1,800	1,350
3	4 40	38 542	27,361	14.400	10,800	1,800	1,350
3½	5.13	28,316	20,100	14,400	10 800	1,800	1,350
4	5.86	21 680	15,390	14,400	10,800	1,800	1.350
5	7.33	13,875	9 850	14,400	10,800	1,800	1,350
6	8.80	9,635	6,840	14,400	10 800	1.800	1,350
7	10.26	7,080	5,026	14,400	10,800	1,800	1,350
8	11.73	5.420	3,848	14,400	10,800	1,800	1,350
9	13.20	4,282	3,040	14,400	10,800	1,800	1,350
10	14.66	3,468	2,462	14,400	10.800	1,800	1,350
13.5	19.9	1,900	1 350	14.400	10,800	1,800	1,350

ral of the greatest recent improvements in railway cars have been made. These have resulted from the formation and bringing into practical use, on this road, two kinds of cars; one of which having friction wheels pendant upon the ends of the axles of the road wheels, the other a plain, simple, chilled box, with outside bearings and steel pointed journals; and from the use of the *cone and cylinder* wheel. And there is no doubt that the cars in use on this railroad are by far the best extant, in Europe or America.

From a set of experiments made on the Baltimore and Ohio railroad, the relative friction, or the force of traction on a level, will be, with a full load, when the chilled box car is used, the $\frac{1}{258}$th, and when the Winans' friction car is employed, the $\frac{1}{450}$th of the weight of the car and its load. The experiments were made with two cars of each kind, and the results just given are the averages. To meet practical imperfections, some allowance must be made; but there is no doubt, that, in practice, these ratios will be the $\frac{1}{240}$th and the $\frac{1}{400}$th, at the least. The diameter of the wheel is 30 inches, and that of the axle, where it is subject to friction, 2 inches. If the wheel should be enlarged to 36 inches, as will probably be the case, as is now preferred in England, then the relative friction will be reduced in the proportion of 36 : 30, and the ratios for the two cars will be $\frac{1}{288}$th and $\frac{1}{480}$th. Moreover, whilst it is believed that the diameter of the axle cannot be reduced in the Winans' car, lest its attrition should prove injurious to the friction wheel, yet it is otherwise with the chilled box car, and the axle now employed for this car has a diameter of $1\frac{3}{4}$ inches. This, again, has the effect of reducing the effect of the friction in proportion as 2 : $1\frac{3}{4}$. Hence, in the chilled box car, with 30 inch wheels, as now used on the Baltimore and Ohio railroad, the traction on a level is the $\frac{1}{274}$th, and, with a 36 inch wheel, the $\frac{1}{329}$th. And these may be set down, in practice, at the $\frac{1}{264}$th and the $\frac{1}{300}$th.

The limits of practical perfection, then, of the two kinds of cars now in use on the Baltimore and Ohio railroad, when wheels three feet in diameter shall be employed, will be such, that, with the one, 1 lb. traction will draw 300 lbs., and with the other 450 lbs. Whilst, at present, as they are now furnished on the Baltimore and Ohio railroad, with 30 inch wheels, 1 lb. will draw 264 lbs. upon one car, and 400 lbs. upon the other.

Through the perseverance of our ingenious countryman, Ross Winans, the inventor, and the patronage of the Baltimore and Ohio Railroad Company, the friction car has gradually assumed more fitting proportions and consistency of parts, until it has arrived at a practical state that will ensure its use upon railways. In all our comparisons, therefore, of great lines of railway and canal, we are fully authorized to assume the traction necessary with this car upon railways, when three feet wheels shall be used; but, as hitherto, $2\frac{1}{2}$ feet wheels have been running upon the Baltimore and Ohio railroad, and as it may be more satisfactory to some that the comparison, in relation to friction, should not, in behalf of the railway system, contain anything not experimentally tested, we shall, for the present occasion, employ the traction of the $\frac{1}{400}$th.

With this measure, let us correct the Table V, page 189, of Doc. No. 18, which Tredgold, seven years ago, formed with a view to his then opinion of a traction of the $\frac{1}{144}$th, and we shall then see in what relation the effects of a given power upon railways will stand, when compared with those upon canals and turnpike roads.

TABLE V—Corrected.

A TABLE showing the effects of a power, or force of traction, of one hundred pounds, at different velocities, on Canals, Railroads, and Turnpike Roads.

Velocity of motion.		Load moved at a power of 100 lbs.					
Miles per hour.	Feet per second.	On a Canal.		On a level Railway.		On a level Turnpike road.	
		Total mass moved	Useful effect.	Total mass moved.	Useful effect.	Total mass moved.	Useful effect.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
$2\frac{1}{2}$	3.66	55,500	39,400	40,000	30,000	1,800	1,350
3	4.40	38,542	27,361	40,000	30,000	1,800	1,350
$3\frac{1}{2}$	5.13	28,316	20,100	40,000	30,000	1,800	1,350
4	5.86	21,680	15,390	40,000	30,000	1,800	1,350
5	7.33	13,875	9,850	40,000	30,000	1,800	1,350
6	8.80	9,635	6,840	40,000	30,000	1,800	1,350
7	10.26	7,080	5,026	40,000	30,000	1,800	1,350
8	11.73	5,420	3,848	40,000	30,000	1,800	1,350
9	13.20	4,282	3,040	40,000	30,000	1.800	1,350
10	14 66	3,468	2,462	40,000	30,000	1,800	1,350
13.5	19.90	1,900	1,350	40,000	30,000	1,800	1,350

From an inspection of the *corrected* table, it will appear, that, when the velocity is 3 miles per hour, (instead of 5 miles, as indicated in the former table,) it requires less power on the railway than on the canal, to produce an equal effect. From a strict calculation, it will be found that the power required will be *equal* when the velocity is $2\frac{86}{100}$ miles per hour, or 4.2 feet per second.

According to Tredgold, the maximum of useful effect of the labor of a horse will be obtained from a duration of 6 hours of labor per day, at a velocity of 3 miles per hour, and the mean power of traction will be 125 lbs. The railway will, therefore, have the advantage of the canal, at a rate of speed best suited to the action of the horse. And it will also appear that the effect on the railway is to that on the turnpike road as 22 to 1.

We see, therefore, that the comparison between canals and railroads is vastly more favorable to the latter, than when Tredgold, in his treatise on railroads, remarked, that, "recollecting that railroads are yet in an imperfect state, while the united talents of our civil engineers have been chiefly devoted to canals for about a century, we may confidently hope that there is yet scope for improvement; and we may fairly infer, that, for new works, railroads will, in nine cases out of ten, be better adapted for the public benefit than canals."

Seeing, therefore, that the improvements in railways and cars have been such, that, with a velocity of 3 miles per hour, the effect is greater than on a canal, and that, at higher velocities, the effect will be vastly more decided in favor of the railway, in consequence of the resistance in the canal increasing in a duplicate ratio of the velocities; and when we also reflect upon the

very great improvements which have, in the last two or three years, been made in the locomotive steam engine, and consider the paramount importance of speed and certainty to a travelling and commercial people, more especially in a country of such extended surface as the United States, *and that this avenue of communication will be open throughout the year*, in winter as well as in summer, shall we hesitate to say, what the author just quoted would, under the same circumstances, undoubtedly say, that the railway should be preferred in ninety-nine cases out of a hundred?

As the late edition of Wood's Treatise on Railroads has not been mentioned in Doc. No. 18, it is probable the compiler of that document had not seen it. And, inasmuch, as the chapter which treats of the comparative merits of canals and railways has been improved in this edition, and likewise contains a commentary upon experiments said to have been made in Scotland, tending to show the practicability of high velocities upon canals, (See Doc. No. 18, page 31 to 34;) it is thought proper to give that short chapter at length; it is accordingly appended hereto, and marked No. 1.

In estimating this chapter, however, a similar correction, though not to the same amount, must be made, as has been applied to Tredgold's table V. Owing to the improvements already mentioned, the canal although with horses at a speed of two miles per hour, it is superior to the railroad so far as regards the effective power of traction, yet, it is not so, in as great a proportion as 3 : 1, and instead of an equality of effect taking place at $3\frac{1}{2}$ miles per hour, as Wood has it, we have shown that the effect of the power of traction with Winans' cars on a level railway, will be equal to that on a canal, when the velocity upon each is very little more than $2\frac{3}{4}$ miles per hour; whilst, at 3 miles per hour, the performance on the railway will evidently preponderate.

To show the performances of locomotive engines according to the state of improvement which existed in the year 1830, and their comparison with respect to the power of horses upon railroads, certain copies of tables, and extracts from the same work, are also annexed, marked No. 2.

In the year 1828, the power of the locomotive engine was no more than sufficient to propel itself up an ascent of 1 in 96, at the rate of 10 miles per hour, without dragging any load after it. In the course of two years after, however, such were the improvements made in this engine, that it could draw up that ascent, a train of cars, weighing, with their freight, 17 tons, at ten miles per hour; at the same time, it could draw, on a level, at the same speed, $53\frac{4}{10}$ tons; at 15 miles per hour, 30 tons; and at 20 miles per hour, 15 tons.

Of the cost of motive power.

According to Tredgold, the power of traction of an average horse, is 125 lb.; and his useful effect is a maximum, with a velocity of 3 miles per hour, continued six hours in the day. The resistance with the Winans' car, is the $\frac{1}{400}$, and the gross load for one horse will be $125 \times 400 = 50{,}000$ lb. $=$ $22\frac{32}{100}$ tons, drawn 18 miles in a day. Deducting one-fourth part for the weight of the cars, the freight will be $16\frac{74}{100}$ tons drawn 18 miles per day. But, as the most economical ratio of weight between that of a car and its load is 1 : 3, and as the weight of a car to carry 3 tons, is 1 ton; we shall therefore, on the present occasion, assume the proper weight of each car to be one ton, and its freight 3 tons, as a general rule upon great lines of railway. The horse will not draw six of such cars when fully laden: his load must, there-

fore, be five cars, containing 15 tons of freight drawn 20 miles (and not 18 miles) in a day, equal to 300 tons drawn one mile in a day.

One man may drive two horses, but we shall, at present, allow a man to a horse, and 5 cars. The average daily wages of a man will be about 80 cents, including board, and the average cost of a horse, including harness and every other expense, about 40 cents; of both together 120 cts. $= \frac{120}{300} = \frac{2}{5}$ of a cent per ton per mile.

The five Winans' cars will cost, in their construction, $750, and they will probably have to be renewed after five years' use; at the end of which time the materials will be worth $250; loss $500. The annual incidental repairs, for five years, may be set down at $80; and, supposing one third part of the entire number of cars to be inactive at depots, sidings, and shops, then the calculation of the expense attendant on these cars will be as follows:

1. Annuity to produce $500 in 5 years; interest a 5 per cent. per annum, - - - - - -	$90 51
2. Interest on $750 at 6 per cent. - - - -	45 00
3. Annual incidental repairs, - - - -	80 00
4. Interest on spare cars, one-third, - - -	15 00
Amounting to - - - - - -	$250 51

300 tons conveyed 1 mile in a day, for the year of 312 days, make 93,600 tons conveyed 1 mile, at an expense, for cars, equal to $230 51. The expense per ton per mile will, therefore, be $\frac{23051}{93600}$ = a little less than one-fourth of a cent, or, more exactly, .2461 of a cent.

The consumption of oil with the Winans' car is exceedingly small, perhaps not so much as the one-twentieth of a cent per ton per mile, and the summary will be as follows:

Cost of drivers and horses per ton per mile, - -	= .4 cts.
Do of cars, - - - - - -	= .2461
Do of oil, - - - - - -	= .05
Amounting to - - - - -	= .6961

or a little less than 7 mills per ton per mile, when one man drives one horse.

It is, however, considered practicable for each man to conduct two horses, in which case half the wages of a man, or 40 cents per day, would be deducted in the foregoing calculation, and the expense of transportation, including cars and oil, would then be $5\frac{3}{5}$ mills per ton per mile.

If to these amounts we add 10 per cent. to cover the pay of agents employed to regulate the transportation and contingencies, which is conceived to be ample on a line where much business is correctly carried on, there will result $76\frac{1}{2}$-100 of a cent per ton per mile for the cost of transportation, when each man drives one horse, and $\frac{62}{100}$ of a cent per ton per mile, when one man drives two horses; and the gain in the latter case will be 19 per cent.

It must be borne in mind that the foregoing estimates are predicated on the assumption that common, or medium horses only, so far as regards their power of traction, are to be employed, whilst the cost is enough to command horses of a heavier draught, and yet sufficiently active for the purpose required.

Upon the Cumberland road, and, indeed, throughout from Baltimore to Wheeling, the turnpike road is very hilly. The maximum grade employed

in the location and construction of the road, was 5 degrees, equal to about 1 in $11\frac{1}{2}$, and there frequently occur stretches of road for miles together, ascending mountains at an ascent of 1 in 12. Let us see what is here the actual draught of a horse. The common load for a team of five horses is 4,500 pounds of freight, plus 3,000 pounds for weight of wagon, equal to 7,500 pounds, or 150 pounds per horse. The resistance on a level is the $\frac{1}{18}$th of this, equal to 83 lbs., whilst the gravity on the ascent is the $\frac{1}{12}$, or 125 lbs. But the resistance in passing up the ascent is the sum of these, that is, 208 lbs. Moreover, the horse has, in addition to this, to overcome the gravity of his own body, which, if he shall weigh 750 lbs. is $\frac{750}{12} = 62$ lb. This added, shows the force of traction to be really 270 lbs. when all the five horses draw simultaneously, and equally, and the road is good. These conditions, however, are frequently not verified, and there is doubtless a necessity in this service to employ horses that shall be capable of exerting a muscular energy of 300 lbs at the least. Now, the proper constant working energy of a horse, (and it is the same with mechanical agents, of all kinds, including the steam engine) is the one half of his capable energy. See note, p. 68, also p. 84, Tredgold's Treatise on Railroads, N. Y. ed. 1825. Consequently, the horses employed upon the Cumberland road, are capable of a constant draught, during 8 hours each day, of 150 lbs. And this happens to be the same as the horse power established by engineers as the unit of measure in reckoning the power of the steam engine.

The time these horses employ in performing the trip from Baltimore to Wheeling, 266 miles, over this hilly road, is usually 15 days, averaging 18 miles per day; and they could, with equal, if not greater ease, travel 20 miles per day, on a railroad, with the same draught. Upon the level parts of the railway, the horse could occasionally take advantage of the momentum of the load, and relax his traces, whilst, upon the descending parts, his load would at all times be less than ordinary, and where the descent was 15 to 20 feet per mile, he would be entirely free from draught, inasmuch as the gravity would equal, and perhaps exceed the friction of the cars. Moreover, upon the railway, he would be entirely relieved from *holding back*, for, in case the gravity upon a descending part of the *way* should exceed the friction, the conductor of the train would apply the *brake*, and effectually regulate the motion of the cars; and, we may remark, by the way, that, upon a canal, the draught is necessarily almost a contant tug, and does not admit of relaxation without coming to a pause, when there is a loss of time; added to this, the animal has to draw at the end of a long elastic rope not parallel to the direction of motion, thereby suffering a partial distress, together with a loss of effective power in the ratio of the co-sine to the sine of the deviating angle.

We see reasons, therefore, for the conclusion that, in general, the horse will work and thrive better in operating upon a railway than in tugging upon the tow-path of a canal.

Having shown that the horses employed upon the Cumberland turnpike road are competent to a traction of 150 lbs. each, and that they could exert this force for 20 miles a day on a railroad, we will next compare their power with that counted upon in the preceding estimates in relation to horse power upon the railway. We there assumed the working power to be 125 lbs.; hence, the double of this, or 250 lbs. will be the muscular energy of this horse. He would, therefore, not be so powerful by 20 per cent. as one of

those which have to work upon our turnpike roads, and he would be entirely inadequate to the work that has there to be performed.

Unless the railway, therefore, is exactly level, there will be a decided advantage in using the more powerful horse, since he will be able, with the same train, to surmount ascents that, with the weaker horse, would be impracticable. At the same time, it is not recommended that the stronger horse, though able to draw *six* cars, should be made to draw a train of more than five, on a level, inasmuch as he would be able, with this load, to traverse occasional ascents of from 15 to 20 feet per mile, whilst his speed would be somewhat augmented on the level parts, in order to compensate there for his want of a full load. It is proper to state, however, that the load of this description of horse being precisely the load of the other augmented by one-fifth of it, that is, six laden cars, the useful effect, when measured as it should be by the relative cost of transportation, will exhibit a gain of ten per cent. since, in pursuing the calculation, the cost in the case where one man attends one horse is found to be the $\frac{69}{100}$ of a cent per ton per mile, inclusive of agencies and contingencies. There cannot be a doubt, therefore, that upon a railway that shall undulate in its grade within the limits of 20 or even 30 feet per mile, the transit will be effected with horses at a cost varying very little, if any, from three-fourths of a cent per ton per mile; and, in all cases where the descent of the line shall be in the direction of the movement of the greater tonnage, as will often be the case, the cost may be reduced even to $\frac{1}{2}$ a cent. This is the result when each man drives but one horse, but if one driver shall conduct two horses, the three-fourths will be reduced to three-fifths of a cent per ton a mile.

Upon the whole, therefore, and considering that the cost of subsistence and labor will continue to be cheaper in the interior of the country than is here calculated upon, there does not appear any valid reason to estimate the cost of transportation of commodities by means of horse power, at a rate per ton per mile greater than three-fourths of a cent.

It is true, that to effect this result, the railway, the machinery, and the management must be good. But what object is there, to which the attention of man is properly and lawfully directed, that does not merit, if it does not absolutely require industry and systematic attention? In Doc. No. 18, herein before referred to, in the letter from Benjamin Wright, civil engineer, is this sentence, p. 174, to wit: "But the great advantage a canal will always have over a railroad, consists in the little mind or thought that is required to use it:" an objection, which, no doubt, canals themselves had once to encounter, and which would be equally valid against the steam engine, steamboats, and a host of other splendid inventions and improvements; if, indeed, it does not (though certainly unintentionally) strike at the root of all advancement in the application of science and the arts to the improvement of our physical and mental condition. Are our countrymen prepared for this objection? Shall a people who have assumed the responsibility of self-government, and, in consequence, have become a great nation, refuse to applaud the genius of their Fulton, and demur at the further advancement of their country in the mighty march of improvement, in order to repose ingloriously in littleness of thought and inactivity of mind? Certainly not. The genius of the people forbids it, and the age forbids it. Judge Wright thinks he is probably in the minority in the United States on the question between railroads and canals, and that the public mind doe- not take all circumstances and bearings into consideration when they unders

take to give opinions. He says, also, (p. 174) in the case of the Baltimore and Ohio railroad " we are kept in the dark about wear and tear."

The expression " kept in the dark," seems to imply a belief in the mind of the respectable writer, that all was not as it should be; that *something* was kept hidden that ought to be divulged or communicated to the public. Now, the fact is, the company have never yet been prepared, nor have their works been so advanced or matured, as to enable them to make definite and official statements of wear and tear to the public in their annual reports, that could be relied upon in determining important principles, much less of exhibiting *practical results* that should fix the precise amount or relative degree of wear and tear. And, until they can make statements which are not calculated to mislead, and which shall be freed from the contingencies incident to a new work of a comparatively new description, and from the expenses incident to the bringing to practical perfection of two new kinds of cars that it is believed will be found superior to all others hitherto employed upon railways, they will no doubt be excused. It is conceived that the public will be much less interested in knowing the amount expended in the inventing and perfecting of a machine, than in its powers and the expenses attendant upon its employ when brought into practical use. Nevertheless, I have, on the present occasion, given an approximate estimate, according to the best of my judgment, of the probable practical cost of the Winans' car, and its wear and tear, and this will be the most expensive of the two kinds, not only in the construction, but in the wear and tear.

With regard to the criticism preferred in pages 198, 199, of Doc. 18, in relation to the expenses of transportation on the first 13 miles of the Baltimore and Ohio railroad, as stated in the 5th annual report of the company, in which the passengers are rated at 12 to the ton, and, after adding the tonnage thus made out, to that of the commodities calculated from the actual expenses incurred, the author infers that the cost of moving power is more than $4\frac{1}{2}$ cents per ton a mile. It may be remarked, that the expenses in the incipient stages of all new works, will range far above the average of what they will be when every thing comes to be regular and systematic. But, in this instance, the result is as unfavorable as can well be conceived, inasmuch as, coupled with the disadvantages already alluded to, a much greater number of men and horses had to be kept in pay and on hand than were sufficient to afford the effective power exerted in the nine months. As the weather was fine or otherwise, the passengers of pleasure were numerous or none at all; yet, still, establishments had to be every day maintained to the extent adequate to the demand of *any* day. But, further, in consequence of passengers not being paid for by the ton, it does not appear fair to bring this item to the standard of so much per ton per mile; and, what is of so much consequence with regard to this deduction, is, that it should be recollected that much the greater part of the gross tonnage was conveyed *by horses* at the speed of *ten miles per hour*. Now, the effect of a high velocity with a horse in lessening his useful effect is very great. In table VI. p. 169, Tredgold's treatise, already referred to, it is shown that the useful effect of a horse, when working on canals, at ten miles per hour, is only the $\frac{1}{79}$ of that which it would be with a velocity of $2\frac{1}{2}$ miles per hour, whilst, on railways and turnpike roads, it would be the one-fourth part. We see, therefore, that although the action of the horse has such a decided advantage upon the railway over that upon the canal when the velocities are considerable; yet, even upon the railway, his useful effect, when he is put at a speed of ten

miles per hour, is diminished three-fourths; and, consequently, the expenses of transit would become increased in the proportion as 4 : 1, beyond what they would be with a velocity of two and a half miles per hour.

When these things shall be taken into the account, as it is not doubted they will be by the public, it will be conceded that the results afford no just ground for the disparagement of the railroad system.

It may likewise be stated, that, although the passengers were almost altogether conveyed in carriages made upon the Winans' friction wheel principle, it was otherwise with the freight; much the greater portion of which was conveyed in the chilled-box car. Now it has been shown, that the friction of the first car is to that of the last as $\frac{1}{400}$: $\frac{1}{264}$. We have also shown, that, with the Winans' car, a horse will draw 300 tons, one mile in a day. Consequently, by proportion, as 400 : 264 :: 300 tons : 198—the effective daily work of a horse with chilled box cars, so far as depends upon the friction. But, upon making a strict estimate, proportioning the number of cars in the train, and making allowance for the lesser weight of this car in proportion to its strength, we find the effective power of a horse to be 220 tons drawn one mile in a day; and it will be recollected that the report of W. Woodville, the superintendent of transportation, gives 227½ tons. Although the whole annual charge attendant upon these cars, embracing repairs, renewals of interest on capital, will not be far from $30 for the chilled box car, to $45 for that having friction wheels, supposing two-thirds of their number to traverse 20 miles in a day for 312 days, or 6,240 miles in the year, whilst the residue of the cars shall be stationary for the purpose of repairing, or for other cause; nevertheless, it is conceived that the cost of transportation has been enhanced to an amount beyond what it would have been with the exclusive use of the friction car in the state of comparative durability to which it has recently been brought.

The railway owned by the Lehigh Coal and Navigation Company, at Mauch Chunk, in Pennsylvania, (see Doc. No 18, pages 8, 163 to 173, 178, 199, 201, 211, and 216,) has been, it would seem, much relied upon, not only by the ingenious and respectable superintendent himself, but likewise by the author of the document just recited, as a standard whereby to test the comparative merits of railways and canals. In proof of this, we cannot have better evidence in the one case than the fact that, instead of continuing the railway down the side of the river Lehigh, from Mauch Chunk to the Delaware, at Easton, a distance of 46¾ miles, upon a descent, in favor of the trade, of about 8 feet per mile, a canal and river navigation has been formed, at an expense of $1,558,000, or $33,326 per mile; or, in the other case, than the prominent array of pages in which this railway finds notice in the document.

We shall endeavor to show that the Mauch Chunk railway is not only a peculiar one, but that the results upon it should, in no wise, be held up as a precedent, or as a test of the railway system, much less as an argument in the comparison of that system with canals, unless, indeed, due allowance is made for all the conditions which are peculiar to it, or to those similarly circumstanced.

From the summit near the mines, to the head of the chute or inclined plane at Mauch Chunk, the distance by the railway is 8 miles, with a descent of 767 feet; the descent is nearly uniform, and is, therefore, at the rate of 96 feet per mile, or 1 in 55.

In his official report to the board of managers, dated Philadelphia, 1st mo. 12th, 1829, the superintendent observes: "Perhaps some remarks on our experience with our railroad, on which has been transported upwards of 60,000 tons, may settle the question with some of our stockholders, who have doubted the policy of canaling the valley of the Lehigh, in place of making a railroad." (See Doc. No. 18, p. 164.)

The following estimate, after some remarks regarding the Erie canal, is then presented, to wit:

"*Cost of transportation on our Railroad for the year* 1828.

"Mules and horses cost	$1\frac{1}{3}$	cents per ton	per mile.
"Hands, -	$1\frac{1}{3}$	do	do
"Repairing wagons,	$\frac{2}{3}$	do	do
"Oil for do	$\frac{1}{5}$	do	do
"Total,	$3\frac{53}{100}$	cents per ton per mile."	

The superintendent, it appears, has also published estimates, &c. in the Mauch Chunk Courier, under date of the 5th mo. 20th, 1830, in which he states the cost of mules and drivers for the year 1829, to have been about 2 cents per ton per mile, being a saving over that of the previous year of two-thirds of a cent per ton per mile. The statement proceeds to show that, at the date last mentioned, a further economy, to about the same amount, had been realized; for that the mules and drivers were then estimated to cost only $1\frac{1}{4}$ cts. per ton per mile. The statement is as follows: (See p. 170, Doc. No. 18.)

"*Cost of hands and animal power, from the summit to the end of the "road, descending all the way.*

"28 mules go two trips a day, and draw up 42 coal and 7 mule wagons, (to carry down the mules) each trip, &c. going 32 miles a day; the 42 wagons each carry 33 cwt. coal each trip; total 134 tons.

"28 mules at 33 cents a day = \$9.24
" 4 drivers .90 do = 3.60

"\$12.84 ÷ 134 = 10 cts.

" for 8 miles, or $1\frac{1}{4}$ cents per ton per mile."

The cost of this heavy item, has, therefore, according to the document, been, through good management, decreased, since the year 1828, about 50 per cent. Nor will this be deemed extraordinary, when we reflect that it is impossible for the human mind to embrace, in advance, so as to provide for every contingent circumstance that will have a bearing on the economical management of a new work. It is obviously unfair, therefore, to measure the value of a whole system by a standard so distorted and monstrous as that generally afforded by first experiments.

We shall now proceed briefly, upon scientific principles, to test the value of the descent by gravity, which, it seems, (p. 165) in comparing the cost of transit upon it, with that upon canals, is to be reckoned one of "the favorable circumstances attending that road," inasmuch, as "being located upon a plane descending in the direction of the load, and requiring no expensive or complicated machinery in its use, [it] approximates, in facility of istrant, *to a small canal*," (pages 163-4.)

Forty-two wagons laden with 67 tons of coal, and 7 wagons carrying 28 mules, descend by their gravity, conducted by 4 men, who, with the brakes, regulate the speed; otherwise, the distance being 8 miles, and rate of descent 1 in 55, the velocity would become ruinously great. The descent having been performed in about $1\frac{1}{4}$ hours, the four drivers return through the 8 miles up the ascent of 1 in 55, with the 49 wagons; that is, 21 mules draw 42 empty coal wagons, and the remaining 7 mules ascend with the 7 mule wagons. In order that this round shall be repeated in the day, so as to transport 134 tons of coal daily, the ascent has to be performed at the rate of about 4 miles per hour, for two hours; so that the two entire trips over a distance of 32 miles, are performed, as the day's work should be, in 8 hours; making allowance for detentions at each end of the road, and at the half-way station, where, it being a single railway, the trains have to pass each other.

The labor performed by each mule in a day, in addition to the muscular exertions necessary to his own exertion on a level, is therefore the sum of the forces required to overcome his own gravity, together with the gravity and friction of two empty coal wagons, on 16 miles of railway, ascending 1 in 55, and at a speed of 4 miles per hour. The way is much curved, and some of the curvatures have a radius not exceeding about 160 feet, and there is considerable flange friction. The wagons work with inside bearings and have wheels two feet in diameter. They have about the same model as the English coal wagons with which Tredgold was conversant, and consequently about the same amount of friction, to wit: the $\frac{1}{144}$th.

If the weight of the empty wagon was one-third of that of its load (32 cwt.=3,584 lbs.) it would be about 1,200 lbs.; but, in the smaller wagons, this ratio cannot well be attained: we shall, therefore, in the absence of precise information on this head, assume it at 1,300 lbs. A mule that will perform the work of an average horse, is lighter than the horse, and his weight may be about 550 lbs.

Gravity of the mule = 550 divided by 55	-	= 10 lbs.
Gravity of 2 wagons =2,600 divided by 55	-	= $47\frac{1}{4}$
Friction of do =2,600 divided by 144	-	= 18
Gravity and friction of 1 mule and 2 empty wagons		= $75\frac{1}{4}$

This will be reduced to its equivalent, with a velocity of $2\frac{1}{2}$ miles an hour, thus:

$2\frac{1}{2} : 4 :: 75\frac{1}{4} : 120\frac{1}{2}$ lbs.=the draught of each mule at $2\frac{1}{2}$ miles per hour 16 miles in a day, which is somewhat less than 125 lbs. the draught allowed for a medium horse 18 miles in a day. The difference is probably made up in a small increase of the friction, beyond $\frac{1}{144}$, or it may be that, owing to the manner of working, the effect is, nevertheless, equivalent to 125 lbs. under other circumstances. The difference, however, is small.

We have calculated what the grade of the road should be, that the traction necessarily employed in returning with the empty wagons shall be precisely the same in amount as that used in drawing the loaded wagons, and find it to be about 21 feet per mile, or 1 in 253. At this grade, a horse of medium strength, or a mule, if that animal is preferred, will draw *nine wagons*, as will appear by the following calculation, which will, at the same time, show the force of traction to be the same in either direction. To obtain a correct result in the other case, we took into the account of the gravity of the agent or mule, and we shall do so here likewise.

3584 × 1300 = 4884 lbs. wt. of one wagon and its load, and the weight of the train of 9 wagons is 43,956 lbs. subject to friction, plus 550 lbs. the wt. of mule gives 44,506 lbs. the weight of the entire mass in motion in the descending course, and subject to gravity.

Friction = 43,956 divided by 144 = 306
Gravity = 44,506 divided by 253 = 176.

Take the difference (for the gravity aids,) 130.

There remains, therefore, 130 lbs. traction for the work of the animal.

In ascending, the nine empty wagons will weigh 11,700 lbs. subject to friction, plus 550 lbs. for the mule = 12,250 lbs., the whole weight in motion, and is retarded by gravity.

Friction = 11,700 divided by 144 = 81 lbs.
Gravity = 12,250 divided by 253 = 49

The sum of which is - 130

and the traction, or force exerted, is the same in ascending, as it will be in descending.

The force of 130 lbs. has to be exerted for 16 miles in a day, and this is equivalent to a force of traction of 116 lbs. 18 miles in a day; for 18 : 16 :: 130 : 116. Consequently, this exertion is within that usually reckoned as the day's work of a medium horse.

In this arrangement, the animal makes but one trip in a day, to wit: he travels eight miles down the inclination with the loaded train of nine wagons, and on the same day he is made to return 8 miles up the ascent with the train of nine empty wagons: thus, each animal transports 9 wagon loads of coal in a day, and 28 mules will convey 250 loads in a day.

In the actual arrangement, however, the 28 mules make two trips in a day, each trip conveying 42 wagons, that is 84 wagon loads per day.

We see, therefore, that, as the road is actually graded, and, notwithstanding that the laden wagons descend by their gravity, and that the mules ride in the bargain, yet *the animal power, under these circumstances, has only the one-third part of the useful effect* that it would have if the line had been graded to the best advantage *for such a railway.*

Consequently, the power costs threefold what it would then do: added to this, the outlay upon the *mule wagons*, together with their wear and tear, and their action upon the railway itself, would likewise be saved. And yet, these are the practical results attendant upon the use of a railway that is to give tone to the opposition raised against the whole railway system, when any part of that system conflicts with a canal!

With respect to the wear and tear of wagons, which, upon this road, is reported at two-thirds of a cent per ton per mile, (p. 168, Doc. No. 18,) it must be borne in mind that the cost is estimated on the distance through which the coal is conveyed; which is only one half of that traversed by the wagons, these having to return empty; consequently, the wear and tear of the wagons, in returning, is that much more added to the cost of transportation per ton of freight, than it would be if the wagons were laden in both directions. Again: the cost of wagons upon this road is also enhanced, very considerably, by the mule wagons, since the transportation is taxed with the wear and tear of one mule wagon in running 16 miles for every 8 miles passed over by the coal conveyed in 6 coal wagons, and, likewise, by that occasioned from carrying the mules 8 miles. We must further observe, that this estimate was given as the wear and tear that occurred in the year 1828, and,

therefore, it is augmented by the effects consequent on the high velocities which were employed upon this road in that year. It is not doubted that the causes here mentioned, without supposing any want in the general economy of the concern, either as respects the plans or the constructions, are altogether sufficient to account for this item being more than one-fourth of a cent per ton per mile. With respect to the effects of the high velocity which swell this estimate, as well as that of the cost of repairs of the railway—see "extracts from letters of Mr. White to a distant correspondent, Mauch Chunk, 3d mo. 5th, 1830," (p. 171-2, Doc. No. 18.)

Much reliance has been placed upon the experience with regard to the injurious effects that resulted from the high velocities of 20 to 30 miles an hour, which were employed in the descent upon this road during two months of the year 1828, and conslusions are drawn from thence against the practicability and expediency of high velocities upon all railways. Now, this is a railway on a very limited scale, peculiarly circumstanced, and very cheaply constructed. The way is very narrow, being only three and a half feet in width between the rails, the wagons are consequently narrow in proportion, the wheels are only two feet in diameter, and some of them, those of the mule wagons, for instance, only 20 inches, whilst the track is very much curved, even with a radius of 160 feet; the iron bars constituting the rails, are thin, narrow, and short, having a thickness of three-eighths, and various widths of from $1\frac{1}{4}$ to 2 inches, and they were laid upon cheap wood, which yielded to the pressure. The cheapness of the construction is indicated by the cost, being only $3,050 per mile, inclusive of the graduation of those parts that were not laid upon an old turnpike. The wheels were not coned so as to suit the curvatures, nor so as to prevent the flanges of the wheels from acting against the rails to the manifest injury of the wheels and railway. The centrifugal force in these curvatures with such velocities, doubling the heads of deep ravines, and whirling round the abrupt protuberances from the precipitous mountain side, was awfully great upon this road, as we have more than once personally experienced. The number of revolutions for wheels so small in diameter, was, by far, too great for the useful durability of the parts subject to attrition, unless the journals and boxes had been protected from dust, and otherwise constructed in the very best manner—conditions which cannot have place, it is believed, with bearings inside of the wheels. Nor would *any velocity* secure the advantage of a third trip upon this road in the same day. Viewing all these conditions, we should think it exceedingly evident, that rashness itself would scarcely contend for the higher velocities *here* that could safely and profitably be maintained where every part should be planned and formed upon correct scientific principles, with a view to such a result. And where, but in the want of information with regard to the philosophy of motion and forces upon railways, are we to look for a charitable reason, why the little peculiar railway under consideration, and the operations upon it, should be used as a measure in estimating the value of railways, and the degree of speed admissible upon them?

In the first place, the Mauch Chunk railway is located and constructed and traversed in a manner rendering it impossible that it should approximate, in its effects, to any thing beyond those of "*a small canal*," and its use is suspended nearly one half of the year, in consequence of the canal, to which it is made only an aid, being unnavigable from the effects of frost in that mountain region, or for repairs. In a word, the fate of this railway has been predetermined to be such, that it can at best only belong to a grade of mprovement ranging between turnpike roads and canals; and, in the next

place, we are told with emphasis that in its use it approximates to that of "*a small canal*," and that, in general, railroads must be considered as occupying a place intermediate between canals and turnpike roads.

The useful effect of a horse on the Cumberland turnpike road, of a mule on the Mauch Chunk railway, and of a horse on the Baltimore and Ohio railroad, taking the latter as reported by W. Woodville, the agent of transportation, and performed chiefly with the chilled-box car, will be respectively 7¼ tons, 38½ tons, and 227½ tons, drawn one mile in a day; being in the ratio of the three numbers, 1, 5⅓, and 31⅓; from which it will appear—

1st. That the animal force of traction is rather more than five times as effective on the Mauch Chunk railway, as it is on the turnpike road between Baltimore and Wheeling, whilst, on the Baltimore and Ohio railroad, it is 31 times as effective.

2d. That these effects are about 6 times as great on the Baltimore and Ohio railroad as they are on the Mauch Chunk railway; that a mean between the Baltimore and Ohio railroad and that turnpike being 122 tons, conveyed one mile in a day, therefore the Mauch Chunk railway, in this respect, scarcely reaches to one-third of that mean.

In dismissing this branch of the inquiry, we think it proper to state, distinctly, that it has been no part of our purpose to endeavor to show that the affairs of the Lehigh coal and navigation company have been mismanaged. Far from it. As pioneers in the cause of internal improvement, they have done much, and their efforts should be duly appreciated. Our purpose has only been to exercise our limited efforts defensively, after being driven, as it were, "to the wall," in document No. 18, published and circulated throughout the Union at the public expense, (the right or propriety of which we do not question,) in essaying to make it evidently appear that, whether this railway had been located, constructed, and managed, properly or improperly, scientifically or otherwise, yet the facts attendant upon it were such as by no means to justify the erroneous conclusions which we apprehended might possibly, if left unnoticed, be drawn from the numerous quotations and remarks in relation to this railway, which appear in that document.

The period fixed upon for the duration of wagons upon the Mauch Chunk railway, is four years, as appears in document No. 18, page 170. In our estimate of cars, however, for great lines of railway, we have predicated the amount of cost upon superior plans of construction, and which, it is confidently believed, will ensure more durability, and have assigned five years as the limit of duration. We have estimated the annual expense accordingly, at the same time having due regard to practicability. It may be pertinent here to state that, in the autumn of 1830, we visited the line of the railway of the Delaware and Hudson Canal Company, situated in Pennsylvania, and observed the operations upon it. At Carbondale, we were particularly informed by the engineer and the superintendent in relation to the cost of repairs in the wagon department. Each wagon carried 2¾ tons of coal; had 3 feet wheels and inside bearings, the body resting upon the axles by means of cast iron *chairs* or *seats*, which, like those of the old English coal wagon, were not *chilled* or hardened; consequently elicited the more friction and wear and tear. This wagon, however, compared very well with those at Killingworth, England, and had the same friction, to wit, $\frac{1}{200}$ths. Their first cost is $120. The following is our memorandum made on the occasion, at Carbondale:

"*Wear of Wagons.*

"The bodies or beds must be renewed every two years. These bodies cost $30. The iron work would be good at the end of the two years, and thus the renewing would cost about $10 or $5 per year. The wheels will last five years, if well chilled, but, with the loose wheels, the flanges will wear out first, to wit: J. Archbald, the superintendent, thinks in three years, and hence they are going to adopt the method of fast wheels as decidedly the best.

"The seats must be renewed once a year. They cost about $1 75 per wagon. The axle must be taken off, and new collars put on, and turned once a year; cost $3 00; add for contingencies, such as repairing brakes and other matters, $5 25 per annum; making the annual repairs of a wagon, $15 00."

In order to perpetuate the wagon, we must add, for the renewing of the wheels, say $7 75 per annum, and $7 20 for interest, *plus* $2 40 for interest on spare wagons; the whole amounting to $32 35, as the entire estimated annual charge incident to the use of a coal wagon used on this railroad.

The wagons are made to travel 4 miles per hour on this railway, and they will therefore make one trip in a day, to wit, 16 miles with coal, and 16 miles back empty. The operations upon this railway being also affected by the navigation upon a canal, we will assume 225 days as the duration of the year's work; and one wagon will carry in a year $2\frac{3}{4} \times 16 \times 225 = 9900$ tons coal, one mile, for 3235 cents; being $\frac{1}{3}$ of a cent per ton per mile, and just one half the estimate at Mauch Chunk, given in page 164, document No. 18.

The cost of coal wagons, however, will continue to be greater than that of cars on other railways, in consequence of the greater wear and tear of the bodies.

With regard to the cost of transportation on this railway, between Carbondale and Honesdale, I have no doubt that it is three or four fold more than it would be on a level railway of equal length, even with the imperfect wagons there employed. A level road would be 16 miles in length. From Carbondale, the coal is elevated to the summit of the mountain at Rix's gap, by means of five stationary steam engines, that work as many inclined planes. There are short levels between, worked by animal power, and there is from the mines to the foot of plane No. 1, at Carbondale, a distance of 2250 feet, having an ascent of 1 in 75, also worked by horses. The whole altitude overcome in ascending the mountain is about 850 feet. The wagons used, have a friction in equilibrio with gravity, on an inclination from a level of 26.4 feet in a mile. Wherefore, the power of traction would be doubled on an ascent of 26.4 feet in a mile. Hence the gravity opposes an ascent of each 26.4 feet, with a force equal to that opposed by the friction on a mile of the level parts of the railway; and, consequently, as many times 26.4 as is contained in 850 feet, the rise of the mountain, by just so many miles of level road, would it virtually lengthen the distance. This will add 32 miles to the 16. Again: although the roads descend about 700 feet by gravity upon self-acting planes, yet the cost of ropes and other machinery is so considerable, that I doubt not other sixteen miles should be added; and we thus conclude that a level railway, 64 miles in length, between Carbondale and Honesdale, would be as economical as the present one, which is only 16 miles in length.

Benjamin Wright, whose name has been already mentioned, had, it appears from page 173, document No. 18, examined into the cost of transpor-

tation on this railway, at the desire of the company, and reported the cost to be from $3\frac{1}{4}$ to $3\frac{1}{2}$ cents per ton per mile; and we have every confidence in the correctness of his statement. When we visited that road, we found it to be about $3\frac{1}{4}$ cents per ton per mile, when the quantity of coal transported was 250 tons daily. But the engines and machinery were calculated for a transit of 400 tons daily, and it was the opinion of the superintendent, when the latter mentioned tonnage should be passed, which they expected to effect, the cost would be reduced to about $2\frac{1}{3}$ cents per ton per mile, or $37\frac{1}{2}$ cents for the 16 miles.

Taking, however, the cost at $3\frac{1}{4}$ cents, and equating for a level road, we have 64 : 16 : : $3\frac{1}{4}$ to very little more $\frac{3}{4}$ of a cent per ton per mile.

Inclined planes, worked by stationary power, become quite expensive per ton per mile, however, when the tonnage is so small as 250 tons per day, or about 56,000 tons in a year of 225 days, which, it appears, is the time calculated upon for the navigation that is to connect the market with the railway. Let the quantity be increased to from 500 to 1000 tons per day, which it should be on a great line of railway, and let the railway be untrammelled by a canal, so that it could continue active through the winter season, and the case will be widely different.

It should be recollected that the Delaware and Hudson Canal Company have had the honor of being the first in America to introduce the stationary steam engine system upon a railway. May they be well rewarded for their enterprise!

Presuming that it will not be doubted by any one that so small a quantity as 56,000 tons per annum is transported 16 miles across a mountain summit 850 feet in height above the termini of the road, in the manner that has been mentioned, at a cost of about $3\frac{1}{4}$ cents per ton per mile, including the pay, hire, boarding, and feeding of all the men and horses, and the cost of harness; also superintendence and the depot expenses at Honesdale; also the expenses of working the engines, fuel, and engineering; the repairs of ropes and of wagons, and the supply of oil; do we not see how entirely practicable it is to pass the Alleghany mountain, from the eastern to the western waters, in precisely the same manner? It would not require more than double the altitude already mentioned, and perhaps not so much, to connect the parts of the railroad upon which the locomotive engine could ply on either side, by a line of railway without a tunnel, that should be worked with stationary power. The length of this part of the railway, as it would overcome, say double the height, would likewise be twice the length of the railroad of the Delaware and Hudson Company; consequently, since the fuel would be equally abundant and cheap on the Alleghany, the transportation should not cost more than on that road in the distance embraced by the system of inclined planes and stationary engines, notwithstanding that the amount of tonnage should be vastly less than that which would unquestionably pass upon a railway that should connect the tides of the Chesapeake with the steamboat navigation of the Ohio. When passengers shall be added to the conveyance, as they will be across the mountains, the railway being continuous and operative throughout the year, it could not fail to be immensely profitable, as a stock, and proportionably advantageous to the country.

The charge for the carriage of commodities from Baltimore to Wheeling, on the turnpike road, averages about 2 cents per lb. or $44 80 per ton on the whole distance of 266 miles, being at the rate of about 17 cents per ton per mile!

We will now compare this with what may be the cost of transit per ton per mile over that part of a railway to connect the Chesapeake and Ohio, which would be much the most expensive to manage, as it would necessarily be incumbered with the stationary system and inclined planes. Length 32 miles.

The route may be supposed pretty expensive, and may probably cost $20,000 per mile in the construction, or $640,000. Sixteen stationary steam engines, houses and fixtures, at $10,000 each, ($6,000 was the cost on the Delaware and Hudson railroad, but these should be more powerful,) is $160,000, making together $800,000, or $25,000 per mile; the annual interest of which is $1,500, and, for the present we shall assume the repairs of the railway at $500 per mile per annum. The annual charge for the capital, including repairs of the railway, therefore, is $2,000 per mile.

We shall now assume, (which will be too low) that only about thrice the tonnage shall pass the Alleghanies, *in both directions*, in the year of 312 days, that has been mentioned as passing *in one direction only* on the Delaware and Hudson railroad, in 225 days, to wit, 150,000 tons. A toll of $1\frac{1}{3}$ cents per ton per mile will pay the estimate of $2,000 for interest and repairs; and if we assume the cost of transportation to be equal to that on the other railway, under the disadvantages mentioned above in relation to it, that is, $3\frac{1}{4}$ cents, then the toll and transportation together will amount to $4\frac{7}{12}$, or a little exceeding $4\frac{1}{2}$ cents per ton per mile.

It is highly probable, therefore, that the entire charge upon this mountain section of the railroad will not exceed the one-fourth part of the present rate of charge upon our turnpike roads. The charge of $4\frac{1}{2}$ cents will not be far from that which the Baltimore and Ohio Railroad Company is allowed by law to make. The investment would therefore be remunerated, while the public could be saved three-fourths of the cost of carriage on the turnpike road, upon a trade immensely augmented.

It will be recollected that this result in the calculation has been attained without allowing any income from the conveyance of passengers, and likewise without drawing to the aid of this expensive section any part of the greater profits to accrue from the more level portions, and which will constitute, by far, the greater part of the entire railway.

Although the stationary system is entirely practicable, yet being more expensive than either that of locomotive engines or horses, that system should not be resorted to upon a level, nor upon grades where the other modes will apply to advantage. It should therefore be employed only where great and sudden changes of altitude have to be met.

In the parallel which we have just drawn between the railway of the Delaware and Hudson Company, and one which should be made to overcome that part of a route across the Alleghany mountain, requiring the stationary engine system, we must not be considered as in anywise indicating the route by which that mountain should be passed by a railway to extend from the Chesapeake to the Ohio, since the point at which the Ohio should be intersected has not been fixed.

Having made this explanation, we shall now claim indulgence while we briefly contrast the railway and canal systems upon the routes surveyed and estimated across that mountain for the Chesapeake and Ohio canal; and, in doing this, we shall not avail ourselves of the estimate of the United States' board of internal improvement, at the head of which was General Bernard: on the contrary, we shall take that stated on pages 122, 3, 4, 5, of document No. 18, as the estimate of N. S. Roberts and A. Cruger, civil engineers.

This section of the route includes the summit level, upon which there is to to be a tunnel four miles in length, piercing the mountain upon a level some 800 feet below its crest; it likewise includes the reservoirs to supply the summit level and contiguous parts with water. The length is 35¾ miles, with 139 locks, overcoming an altitude of 1028 feet on the eastern side of the summit, and 28 locks lifting 224 feet on the western side. The distances and estimate may be stated as follows:

	Miles.	Chs.		
Summit level	5	40	estimated to cost - -	$1,856,056
Eastern side	15	60	- - - -	1,370,618
Western side	14	40	- - - -	503,042
Totals,	35	60	- - - -	3,729,716

This amount upon 35¾ miles is at the rate of $104,320 per mile.

These estimates are predicated upon a breadth of 48 feet, and a depth of 5 feet for the canal, excepting the tunnel, which was to be 22 feet wide, inclusive of 5 feet for the towing path. The cost of the tunnel alone is estimated at $1,610,821; but the author of document No. 18, on page 120, gives his opinion that the width allowed "is about 17 feet less than the greatest utility of the work would require," and, after commenting upon the estimate of the engineers, further advances his opinion that the cost of the tunnel should be "put down at $2,200,000, including all contingencies."

We shall proceed, however, without correcting the estimate of the engineers, as is here recommended, although it is much less than the sum estimated by the United States' board of internal improvement; and it will be observed that, supposing, in case of a railroad, the tunnel should be dispensed with, then the proportion of the altitude to be overcome, compared with the distance or length of the road, will be about the same as that of the Delaware and Hudson railroad; or of the one which we had supposed would be required upon almost any route across the Alleghany mountain. And, therefore, the cost per mile of both toll and transportation, will not exceed 4½ cents per ton, as we have already endeavored to show.

Let the cost per ton per mile now be reckoned upon these 35¾ miles of canal, the construction of which is estimated to cost $104,320 per mile.

On account of the great number of locks, and the magnitude of the reservoirs, which would have to be maintained upon this short section of canal, the repairs would go much beyond an average amount for canals, and we think it a moderate assumption to rate the annual repairs, in this instance, at $1,000 per mile.

An allowance for attendance at the locks must likewise be made, inasmuch as, upon the railroad, the cost of transportation, at the same as upon the Delaware and Hudson railway, which included the engineering and attendance at the stationary engines and inclined planes; we shall set down the attendance at only $100 per annum per lock; which, for 167 locks in 35¾ miles, is $467 per mile:

The tolls will therefore depend upon the following items of annual interest and expense per mile:

1. Interest on $104,320, (the cost per mile) - - -	$6,259
2. Repairs per mile, - - - - - -	1,000
3. Attendance at the locks, - - - - -	467
Amounting per annum, per mile, to	$7,726

The toll, therefore, when 150,000 tons shall pass in a year, (as was assumed in estimating for the railroad,) must be $5\frac{1}{8}$, or a little exceeding 5 cents per ton per mile.

The cost of transportation has yet to be added. It is contended by some, that the cost of transportation at $2\frac{1}{2}$ miles per hour upon a spacious canal, (with but little lockage, it is presumed,) can be reduced to half a cent per ton a mile. If we take this favorable assumption, and allow the speed to be $2\frac{1}{2}$ miles per hour, when there is one lock to the mile, the time employed in passing $35\frac{3}{4}$ miles will be 14 hours. In addition to one lock to the mile, there will here be 131 locks, and the time allowed for passing them, according to the estimate of the United States' board of internal improvement, (see page 101, document No. 18,) is 17 hours. The whole time spent in passing these $35\frac{3}{4}$ miles of canal will, therefore, be 31 hours, and the cost of transportation will be proportionably increased; then 14 : 31 : : $\frac{1}{2}$ a cent: $1\frac{1}{8}$ cents per ton per mile.

The entire cost, therefore, to be charged upon this section of the canal, will be (according to the data) $6\frac{1}{4}$ cents per ton per mile; whereas upon a railroad, worked upon the stationary engine system, it will not exceed $4\frac{1}{2}$ cents.

It must be borne in mind that this comparison is founded solely upon the freight of commodities; that the railroad will be relieved, to a considerable extent, by the receipts from the conveyance of passengers and the mails, whilst the tolls upon the canal, independent of the transportation, would exceed both the tolls and transportation of commodities on the railroad.

It must likewise be recollected that we have transferred the cost of transportation found to obtain upon the Delaware and Hudson railroad, when the quantity transported daily was only 250 tons, or 56,000 tons per annum, to the estimate for the railway across the Alleghany; but it should be remembered, that the rates of transportation by means of stationary power, becomes much reduced when the engines and planes are worked more nearly to the limits of their full capacity. The steam, engines, machinery, and attendance, will remain to be very nearly the same. We feel authorized, therefore, to estimate the cost of transportation by means of stationary engines when working to the best advantage, where coal is as cheap as it will be on the Alleghany at $1\frac{1}{2}$ cents per ton per mile, at the most.

If it be said that double the tonnage which we have allowed, or 300,000 tons per annum, will pass the mountains, we say, in that case, that the capacity of the engines and planes will be competent to this, and that the cost of toll and transportation by the railway would not exceed $2\frac{1}{2}$ cents per ton per mile, whilst it would still be as much as $3\frac{3}{4}$ cents by the canal.

So recently as the beginning of the year 1829, the relative economy of the stationary and locomotive systems, upon level railways, or upon those but slightly inclined, was warmly contested in England, and the question was not put at rest until the recent improvements in the locomotive engine, already alluded to, took place.

About that time, the directors of the Liverpool and Manchester Railway Company appointed two engineers of known ability, (Walker and Rastrick,) to examine the railways in England, and to report "what, under all circumstances, is the best description of moving power to be employed upon the Liverpool and Manchester railway." See Reports, &c., Carey & Lea, Philadelphia, 1831. These engineers reported that the amount of freight, to wit, 2,000 tons, might be conveyed daily in each direction between Liver-

pool and Manchester, at the rate of 10 miles per hour, either by the fixed engine, or by the locomotive system; they appeared to incline rather in favor of the former, since they conceived it necessary, in either case, to work the Rainhill and Sutton planes, ascending 1 in 96, with fixed engines Without including the wear and tear of wagons, and rating their friction at the $\frac{1}{180}$, these engineers reported the rate of cost per ton per mile, upon the locomotive principle, to be - - - - .2787 of a penny.
And upon the stationary plan, - - - .2134 of a penny.
And by horse power, - - - - .4500 of a penny.
The latter, when the horse takes back the empty coal wagons. This estimate for horse power was made from the operations of the horse at a speed of 2½ miles per hour, upon the Brenton and Sheelds railway. It should here be noted that the purchase of one such horse, was there, at that time, £40, and his keeping £50 per annum; and we see from this, that the cost of that animal is there twice as great as in the United States.

The report, as has been mentioned, was not very decided as to which system should be adopted, notwithstanding the expense for a very large trade predominated in favor of the stationary plan, each system had its peculiar advantages and disadvantages.

The engineer of that railway, however, was very decided in favor of the locomotive system, and the directors offered a premium of £500 for the best improved engine of a given weight and power. In the course of that year, the locomotive engine received new and valuable improvements, and the question which, for years, had been unsettled, was now determined in favor of that engine. Its relative powers, in 1828 and 1830, have been already stated.

Since the improved locomotives were brought into use, it has been estimated that the expense, per ton per mile, by these engines,
will be - - - - - - .164 of a penny,
And by the stationary system - - - .269 of a penny.

We are not yet prepared to say, from experience, what the cost of conveyance by the locomotive system will be in this country. We think it probable, however, that an engine, capable of conveying 30 tons of freight 120 miles in a day, will cost, including interest, repairs, renewals, engineering, attendance, and fuel, from $9 to $15 per day, according to the price of fuel at the place demanded; and the cost per ton per mile, in the one case, will be ¼ of a cent, and in the other 5-12, or something less than ½ of a cent—more exactly .417 of a cent.

Now the cost of horses and their drivers, was found to be,
when 1 man drives 1 horse, per ton per mile - - .4 of a cent,
and when 1 man drives 2 horses - - - .267 of a cent.

When, therefore, the locomotive engine costs but $9 a day, it will be cheaper than horse power, under either of the foregoing circumstances; but when it shall cost $15 a day, it will cost about as much as horse power.

In all places, therefore, where coal is cheap, the power of the locomotive engine will be cheaper than that of the horse, when the latter moves at a speed of 2½ or 3 miles per hour, and the former at 10 miles.

The great advantage, however, to result from the locomotive engine, does not so much consist in the small saving that there may be in the cost of conveyance at slow speeds, as in the circumstance that the cost of transit by it, will be very nearly as cheap at 10 miles per hour as at any less velocity; and this adds greatly to the capacity of the railway, and lessens the

number of cars necessary to do the same amount of business; while the freight can be carried, without conflicting with the regular and speedy conveyance of passengers, or the mail. Upon some lines of railway, it may become expedient to travel with a velocity of 15, and even 20 miles per hour: and, as any speed, exceeding 10 miles, is obviously beyond the capability of the horse, the locomotive steam engine can, alone, there be used in the conveyance of passengers.

With regard to the cost of transportation upon canals, there are various and conflicting statements, as well as in respect to railways. We have shown that the cost by the latter when level, or slightly departing from a level, may be reduced to about half a cent per ton per mile, with horses, including the cost of cars, and that it will vary according to the number of drivers employed, from that to $\frac{3}{4}$ths of a cents. It appears that, on the Erie canal, the cost, with boats of 40 tons burthen, is one cent per ton per mile, with full loads in one direction, and empty in the other.

The information we personally obtained, in the autumn of 1830, upon the works of the Delaware and Hudson Canal Company, in relation to their canal, was, that two men, a boy, and a horse, would convey a boat, freighted with 25 tons of coal, 20 miles in a day; in October, however, owing to the want of water, the quantity carried was only 20 tons. The transportation was done by contract for $1 50 per ton; the length of the canal being 108 miles, the cost per ton per mile was $1\frac{39}{100}$ of a cent, exclusive of tolls; but they hoped to economize to $1 25, or per ton per mile, $1\frac{16}{100}$. This very well agrees with Judge Wright's statement of "one cent to one cent two mills." See Doc. No. 18, p. 173.

The present cost of transit, on the Lehigh canal, in *rough arks*, is one cent per ton per mile. See Doc. No. 18, p. 173.

With a boat of 75 tons burthen, Josiah White, the superintendent, estimates the cost of transportation on the Lehigh canal to be about $\frac{3}{4}$ of a cent per ton per mile. P. 170.

This is an unusually spacious canal, being 60 feet wide, and 5 feet deep; and there is no doubt that, with a velocity as low as $2\frac{3}{4}$ miles per hour, the traction of a horse would be more effective here than on a level railway, but it would be otherwise at any higher rate of speed.

With respect to the two lesser canals just mentioned, it does not appear that they have any advantage over the railway; as respects the cost of transportation where horses are employed, they would certainly not compare with a railway upon which the locomotive engine could be properly used, not to say any thing as to the advantages which the railway would possess over the canals in the winter season.

The greatest advantages which the railway will possess over the canal, when horse power is employed, will consist in the continuity of the transit upon the railway throughout the whole of the year; as the two most potent enemies to canals, drought and frost, do not prevent operations upon the railway; and, likewise, in its peculiar fitness for the conveyance of passengers, light and valuable goods, and the mails at velocities from 3 to 10 miles per hour—a range of speed, demonstrated, by experience, to be within the powers of the horse, and throughout which, his effects upon the railway predominate beyond dispute.

With regard to the conveyance of persons, light goods, and the mails, it can scarcely be doubted that the facilities offered by the railway system, even with horses as the motive power, beyond those afforded by either

canals or turnpike roads, will be such as to insure to that system a favorable reception, and that railways will be required by the country, even should they be preceded in the order of time by canals. And when it is recollected that the useful effect of horses will be a maximum, at about the same speed at which it will also be equal on both the railway and the canal, to wit, about 2¾ miles per hour, may not the great advantages, to arise from the operations of the railway through the winter season, in equalizing trade, affording regular supplies, preventing scarcities as well as monopolies; taking to the distant market the products of the soil, when the farmer can best prepare his crops for that purpose; rendering unnecessary an expensive and undue accumulation of stock and capital at mills, mines, iron works, and other manufactories, and promoting the general industry; we say, may not these great advantages, attendant upon the conveyance of bulky, heavy, and less costly commodities, when added to that acknowledged even by the advocates of the canal system to exist with respect to the mails, passengers, and light goods, be sufficient to decide the public in favor of the railway system? How decisive will these advantages be, therefore, when the locomotive engine shall be employed, the expense of which will be about the same, at a speed of 10 miles per hour as at any less velocity? See Wood's Treatise, ed. 1831, p. 431.

Cost of construction and repairs.

The graduation and masonry of the Baltimore and Ohio railroad have been completed as far as to Frederick city, 60 miles, and to the "Point of Rocks" at the Potomac river, 67½ miles from the depôt at Baltimore; and a double railway has been laid down through three-fourths of the distance to Frederick, and a single track on the residue of the distance to that city, as well as a single track to the "Point of Rocks," with the exception of a space of one or two miles, which could not be laid on account of the severity of the present winter at its setting in. The materials are collected and collecting for the second track throughout to the Potomac. The branch, connecting the main stem of the road with Frederick, is 3½ miles in length, and it unites with the main line on the western bank of the Monocacy river, 56½ miles from Baltimore.

Almost the whole of the expenses of construction have, therefore, been already incurred, and it is easily foreseen what amount will be required to complete the work to the extent already mentioned. For information on this head, we will quote from the fifth annual report of the President and Directors to the Stockholders made, in October last, as follows: "The actual cost of graduation and masonry upon the 71 miles between Baltimore and the Point of Rocks, including the lateral road to Frederick, will not exceed $1,101,615, or $15,500 per mile; and that the cost of a double set of tracks upon the main stem of the road, and of a single set on the lateral road to Frederick, will not exceed $805,238, or $11,628 per mile of road, with a double set of tracks; thus making the total cost of graduating the entire line of these portions of the road, and of laying the rails upon them, $1,906,853, or $27,128 per mile. About one-third of this line will be laid with stone rails, and the remaining two-thirds with wood."

In this charge is included the heavy expenditures incurred on the first division of the road. According to the report of the superintendent of graduation and masonry hereinbefore referred to, it appears that the gradua-

tion and masonry of the 2d, 3d, 4th, and 5th divisions of the road, embracing the entire line between Ellicott's mills and the Potomac river, and extending over a distance of 54½ miles, will cost $465,443, or $8,540 per mile; if to this be added $11,628, the average cost of laying a double set of tracks on the entire line between Baltimore and the Point of Rocks, the actual cost of graduation, masonry, and laying a double track of rails on the road between Ellicott's mills and the Potomac, will be $20,168 per mile; and this district, it is believed, may be assumed as affording a fair specimen of the labor and expense which will be incurred on the remaining line of the road, from the Point of Rocks to the coal mines in Alleghany county."

We are induced to believe that the fact would not be far from what is here assumed. The distance from the Point of Rocks to Cumberland, by the route surveyed for the canal, is about 140 miles. The route of the railroad, however, would be made to cut off bends of the river which the canal would have to traverse, and it is probable that the line of the railroad would be less than 130 miles in length, say 130 miles, at $20,168 per mile,

is - - - - - - - -	$2,621,840
Cost from Baltimore to the Potomac - - -	1,906,853
And the estimated probable cost of a double railway, from Baltimore to Cumberland, is - - - - -	$4,528,693

We are inclined to the opinion that the actual cost would approximate much more nearly to the amount just given, than the round sum of $5,000,000, as given, in our report, to a committee of the Legislature of Maryland, last winter.

The report, just alluded to, was made to the President of the Baltimore and Ohio Railroad Company at his request, in order to enable him to comply with a call from the Committee on Internal Improvements of the Legislature of Maryland, inquiring "into the relative expense, benefits, and facilities of constructing railroads and canals, with a view of ascertaining to which of these means the funds of the State can be most beneficially applied."

It will be perceived, therefore, that, in making this report, we did not voluntarily enter upon debateable ground, but, from a sense of duty, made such statements and observations as we considered pertinent to the complex inquiry, and which our limited knowledge and ability allowed us to compile.

This report has been noticed in the third annual report of the President and Directors to the Stockholders of the Chesapeake and Ohio Canal Company, in a spirit and style most satisfactory to themselves. The third annual report, however, which contained the criticisms, does not appear to have been accompanied by the report which it professed to review and criticise: it is to be presumed, therefore, that the stockholders are yet unacquainted with that report.

In the hope that the report may be allowed to accompany the remarks in regard to it, and that it may share the public favor to the same extent as the commentary upon it in Doc. No. 18, it is hereto appended and numbered 3. It is asserted, in effect, in Doc. No. 18, page 35, when commenting upon this report, (now numbered 3,) that there were about 10 miles out of the 12, between the "Point of Rocks" and Harper's Ferry, not surveyed by us, and that our survey was "exclusively directed to those narrow

passes, as the only lines of expected interference between the canal and railroad."

We reply, that this is an error on the part of the writer, which he has possibly fallen into from the circumstance that this part of the line of the railway was not definitively, that is, finally located, and staked out ready for contract; all the preliminary suveys and levels, however, were taken for this purpose, and we have not, therefore, spoken of ground with which we were not perfectly familiar.

The reasons assigned in the third annual report to the Canal Company (see 1st paragraph, page 36, Doc. No. 18,) are, no doubt, not the true ones why the construction of the canal should cost more than that of the railroad to which it is parallel; and the advantages over the canal possessed by the railroad, in that respect, upon such ground, are thereby demonstrated.

We are still of opinion, that the expense of constructing a canal from Baltimore to the "Point of Rocks" would be *double* what the railroad *between the same points will cost.* But our "reason" for that opinion was not that imputed to us in Doc. No. 18, p. 38. Upon a reference to that report, which, as before mentioned, is hereto annexed, and numbered 3, it will be found that we did not, on that occasion, detail our reasons for this opinion. The paragraph which it seems has been regarded as containing our "reason," is entirely independent of that in which we gave our opinion in relation to the route between Baltimore and the Point of Rocks. So far, therefore, was the sentence in which mention is made of Doctor Howard's estimate for a canal between Georgetown and Baltimore, from affording the "reason" for the opinion asserted in the paragraph which preceded, that it concerned a route entirely distinct and separate from that between Baltimore and the Point of Rocks.

Exception has been taken to our estimate of the probable cost of walling the inner banks of the canal, (p. 39,) and it is asserted that "more than 40,000 superficial yards, one foot in thickness, of such walls, have already been constructed in the Chesapeake and Ohio canal, at the cost of less than 16 cents a yard, including the price of transporting the stone some distance by land." It is believed that the slope generally given to the interior banks of canals, is 1¾ to 1: with 6 feet depth of water, then, and a bank two feet above the water, the base of the slope of each bank would be 14 feet. It is believed to be necessary, in order to secure the banks from the action of the water, and from the injurious effects of frost, as well as to render the wall itself secure, that it should be based upon the bottom of the canal, and be made to extend to the top of the bank, which is 2 feet above the usual surface of the water. The shortest distance from the bottom of the canal to the top of the bank, measured on the slope, will, therefore, be 16 feet; hence, the number of superficial yards of such a bank, one mile in length, will be 9,387, and of both banks 18,774 yards. At the price of 16 cents, which it is alleged such walling has been built for, the cost for a mile of the canal would be $3,003 84, whilst our estimate was $5,000. This wall is only one foot thick, but we are of opinion it should be 18 inches in thickness, to insure its stability, and to prevent the water from sapping the bank through its crevices: then the cost, if it should be in proportion to the quantity of stone used, would be about $4,500 per mile. An angle of 45 degrees instead of 30, which we have been allowed for the slope, would be preferable when the bank is walled. In situations where artificial embankments form the canal, the walling

should be postponed until these embankments have subsided in their settling, after which they will be found not to have a less slope than 30 degrees, when, to adjust their slope to 45 degrees, would be more costly than to face it at 30 degrees.

In forming a wall one foot thick, $\frac{1}{3}$ of a cubic yard, or $\frac{36}{100}$ of a mason's perch, if stone is employed, and the rule is for the mason to charge the same for a wall 18 inches thick as he would be entitled to for one of that thickness, inasmuch as the facing is the same in either case, whilst the wall of a less thickness must be laid with more care to ensure comparative stability. This charge, therefore, for the laying of $\frac{36}{100}$ of a perch of wall one foot thick, will be the same as for $\frac{54}{100}$ of a perch. Now, if we reckon at the low rate of 25 cents per perch for the mason, and 6$\frac{1}{4}$ cents for his attendance after the materials are all upon the spot, and the banks properly dressed to receive the wall, the cost will be about 31$\frac{1}{4}$ cents per perch, amounting upon $\frac{54}{100}$ of a perch, to about 17 cents as the cost of each superficial yard, *under these circumstances*, instead of 16 cents, the cost alleged. It is unacountable, therefore, how the wall could have been erected for 16 cents a yard, including the transportation of the materials "some distance by land," unless, indeed, we suppose the laborer, as is too often the case in public works, not to have received adequate remuneration.

In addition to the 31$\frac{1}{4}$ cents, there should be added, in making an estimate, an allowance to remunerate the proprietor of the quarry, and likewise for quarrying and transportation; and it will be seldom found that the cost of a rubble wall will be less than from 75 to 100 cents per mason's perch, or, in terms of the superficial yard, from 40$\frac{1}{2}$ to 54 cents. It has been asserted that it is unnecessary to face with stone more than a part of the slope of the bank, at and near to the surface of the water; should this be so, our estimate will have been too high. We should, however, lack confidence in a wall built for 16 cents a yard, and also in one not founded on a level with the bottom of the canal, unless it were based upon a rock.

It is conceded, that, where the materials of which the wall is constructed are excavated in the formation of the canal, leaving a rock bound bank on one side, its cost will be reduced below our estimate, but the excavation account will be fully charged with the quarrying. It will be recollected, however, that it has been said (Doc. No. 18, p. 35) that only about two miles out of the twelve, between the Point of Rocks and Harper's Ferry, are of this *favored* description.

In the earnestness of the commentator to defend his favorite work, it would seem that his imagination has applied to the canal along the Potomac, our remarks in relation to canals in general, and, accordingly (p. 40, Doc. No. 18) treats our judgment in the words following, to wit:

"What shall be thought of the judgment which, under the climate of Maryland, and in relation to the Potomac, pronounces, that from the combined effects of floods, breaches, repairs, drought, and cold, the average duration of the navigation of a canal, *in our climate*, is reduced to about one-half of the year?" And, again: "Does any man believe that the Potomac river will not supply an adequate quantity of water, &c.?"

We will, however, now assert our opinion that a canal across the Alleghanies would be liable to the evil effects of all the causes here enumerated, whilst the injurious consequences of most of them would be felt along the Potomac.

We see no cause to change our opinions, as then expressed, with regard

to the relative merits of canals and railways. Public opinion and public interest will settle the question in due time, and we rest assured, that, at the same time that it is the tribunal of last resort, the decision will be just.

Repairs.

With regard to the cost of repairs upon railways, much has been advanced in the voluminous document now before us, and an estimate has been given (p. 170) amounting to $983 $\frac{60}{100}$ per annum per mile of double track. This estimate is alleged to be founded on the experience upon the Mauch Chunk railway, already described, and has been, it appears, preferred by the superintendent of that road, in a controversial essay, in an answer to John L. Sullivan, civil engineer, who advocated the superiority of railroads over canals.

The next estimate presented is stated in an "extract of a letter from John Bolton, esq., of New York, late President of the Hudson and Delaware Canal Company, to the President of the Chesapeake and Ohio Canal Company, dated, New York, December 17th, 1831." (See Doc. No. 18, p. 176.)

In this extract, it is stated that the repairs of the Delaware and Hudson railroad were estimated, for the year 1831, "at rather more than $1,500 per mile: that the railroad has eight inclined planes; five worked by steam engines, and three by gravity."

It is, however, not stated in the "extract" from the letter of the late President of the Delaware and Hudson Canal Company, nor is it intimated in the wide amplitude of materials which compose Doc. No. 18, in what particular manner this railroad was constructed. Having, in person, examined this railroad, throughout its entire extent, more than once, we deem it our duty, on this occasion, to state that, through the greater part of the 16 miles (which is the whole length of the road,) the railway is mounted upon wooden bridges or trussel work, in lieu of embankments of earth. This frame work is employed upon all the grades of the road, from a level to inclinations of 1 in 12 or 4¾ degrees, and varies in height, from the ground to the railway, from 2 or 3 feet up to 20, 30, and even to 35, feet! It is very serpentine, and is much curved even in parts where the trussels are quite high. Notwithstanding these frail structures were resorted to in places where the grade of the road passed above the broken surface of the ground, which it was made to do on most of the line, and therefore rendering the procurement of earth, for the supply of embankment, unnecessary; yet the abruptness and unevenness of the surface was such that cuts of considerable length and depth, especially in graduating for the planes, had to be made, and as if a preference over embankments had been awarded to these wooden structures, on account of some intrinsic merit which they were supposed to possess, the earth, from the excavations, was not hauled forth upon the descending grade to make permanent embankments for the support of the railway; but, on the contrary, it was thrown out in spoil banks, and, in some instances, with additional expense.

The railroad passing through a dense beech and hemlock forest, these two kinds of inferior timber, but the latter in much the greater proportion, enter largely into the composition of the structures which form the work. In parts of the way, the superstructure is made to rest upon posts planted in the ground, and these posts were not unfrequently of beech. The kind of tim-

ber most convenient to the site of the road was generally employed in the construction.

After this manner, was this railway, from Carbondale to Honesdale, constructed, 16 miles in length across the Moosic mountain, with eight inclined planes, all furnished with machinery, including a length of more than 3½ miles of rope, and 5 stationary steam engines, for the sum of about $200,000.

The original design was to use locomotive engines on those parts not covered by the system of inclined planes, that is, on more than half the distance next to Honsedale at the commencement of the canal.

It was predicted, however, and verified upon trial, that so frail a mode of structure would not admit of the employment of those engines, and the alternative was adopted, of using horses instead. To provide, however, for this change, a horse path of wood had to be laid upon the frame work throughout—thus greatly adding to the expense of construction as well as of repairs.

It is presumed that the bare mention of these facts will sufficiently account for the estimate of $1,500 per annum per mile, as the probable expenses of repairs for the year 1831. Indeed, when it is considered to what extent in height and length these perishable frames have been employed, and how very temporary and frail the structures made in this manner, and of such wood, must necessarily be, and what extent of flooring for the horses to walk upon, remains constantly exposed to the weather, and to the action of the travel, and that the repairs of 3½ miles of rope, together with the machinary and fixtures appurtenant to the planes, must be met, the surprise, if any, should rather be, that the amount required was not greater.

Nor is it to be wondered at that the retiring President, when judging from the only examples with which he was probably familiar, to wit, the railway at Mauch Chunk, and the one which had shared so largely of his enterprise and public spirit, should assign to the advantages of the railway system a place between those of turnpike roads and canals, or look upon the public favor, which is beginning to be put forth in behalf of that system, as a *mania*. (See Doc. No. 118, p. 177.)

We have made an estimate of the probable amount necessary for the annual repairs and renewals of a mile of double railway of good construction, when sleepers of wood, and string-pieces likewise of wood, shall be employed to support the iron bars or rails of the railway, and find the sum necessary for the object to be about $500. It is believed that the price allowed will procure timber that will last twelve years. Some think that southern pine will last beyond the period here assigned. It may be so. But it is conceived that, in the absence of more experience, it may be judicious to assume this period for timber that can be procured for twenty dollars per thousand, *board measure*. If locust or red cedar shall be used, the repairs will be diminished to some extent.

For information with regard to the probable duration of wheels and maleable iron rails, we have compiled a short document, and annex it for reference. It is marked No. 4.

For our estimate of the probable annual repairs of a mile of double railroad, when wood instead of stone shall be used in the construction of the railway—see document No. 5, hereto annexed.

With stone sills employed in the construction, the railway will be formed exclusively of stone and iron, of which two materials, the iron alone will

be subject to loss, from wear and decay; in which case, the construction having been properly executed, the annual repairs of one mile cannot, we think, exceed two hundred and fifty dollars.

As we intimated, with regard to the cost of transportation, so do we say with respect to that of repairs; which will depend upon vigilance, and a judicious direction of means to the end to be attained; and it should never be lost sight of, that much will likewise depend upon the location and construction of the railroad.

Repairs of Canals.

The superintendent at Mauch Chunk, after having concluded his estimate for the repairs of a double railway, as already alluded to, next proceeds to estimate the "wear and tear of the canal" upon the line from Mauch Chunk to Bristol; length 106 miles; fall 524 feet; number of locks 66; lift, 8 feet.

It is assumed that each set of lock gates will cost $500, and that they must be renewed every ten years. The cost of 66 sets of gates will be $33,000; and the tenth of this, or $3,300, is taken as the annual cost, which, being divided by 106, the number of miles, there results $31\frac{12}{100}$ as the cost per annum per mile of this item. See document No. 18, p. 171.

It is next assumed that, "after eight years' duration," one man working 250 days in the year, at $1 per day, will keep in repair an average length of two miles through the whole line from Mauch Chunk to Bristol; and the second, and last item of expense, is calculated to be $125 per mile.

The two items will, therefore, stand as follows:

Repairing lock gates per mile - - - -	$31 12
Other labor - - - - -	125 00
Amounting to - -	156 12

And thus the expense of repairs per annum per mile upon the Lehigh canal, extending down the Lehigh from Mauch Chunk to the Delaware river, at Easton, about 46 miles; and that upon the Delaware division of the Pennsylvania canal, extending thence along the margin of the Delaware to Bristol, 60 miles more, in all 106 miles, is estimated at $156\frac{12}{100}$.

Without calling in question the adequacy of the sum allowed for the repairs of a set of lock gates in ten years, to wit, $500, it is believed that the allowance of $125 would not do more than maintain the towing path in a state of repair, open ditches, drains, and culverts, and keep the banks in good condition. We can, however, conceive of other items of expense, which will as certainly have to be met, as will those two which have been admitted into the foregoing estimate. In an estimate for the repairs of the Lehigh canal, something might have been allowed for renewing the lining of the lock chambers, which is of wood. The locks are built of rubble, laid in hydraulic cement, with frames of timber secured in the face of the walls, to which the planks are fastened that form the lining. A good lock is constructed after this manner, probably at an expense of some $400 per foot lift less than with cut stone. As this form of construction has not generally been employed, and although the repairs contingent upon it could not be disregarded in a full estimate for this particular canal, yet we shall also omit to assign its amount, inasmuch as it is our aim to approximate to that which will be found generally to obtain with regard to the repairs of canals.

There is another item to be provided for, which, if it has not already occured on this canal, will doubtless command attention before the termination of the "eight years," the period which seems to have been fixed upon in the foregoing estimate, during which the embankments shall have subsided, and all "the extraordinary repairs" consequent upon latent defects which could alone be detected after the admission of water into the canal, or such as are inseparable from the necessary weakness of all new works of this description. The item just alluded to, is an allowance for cleaning out the canal after the lodgment within it of sediment, consisting of alluvial deposite, and sand gravel and clay that shall, from time to time, be brought from the adjacent farm lands, and from feeders and streams admitted to discharge their contents into the canal; and likewise from the overflowing of ditches and drains during freshets and heavy rains; and, also, from the washing of the banks.

We profess not to know what amount of materials will annually accumulate in the canal from these causes; but we think, even under good management, it will be quite favorable to the canal to assume an average quantity equivalent to a uniform depth of two inches per annum upon the bottom of the canal; and that, in every six years, if not in shorter periods, materials amounting to a foot in depth will have to be removed.

Supposing the canal to be 40 feet wide at bottom, the number of cubic yards in the mass to be removed per mile, at the end of every period of six years, will be 7,822; and, considering the diagreeable nature of the work, it could not well be expected to be done for less than 20 cents a cubic yard, or per mile $1,564, and the annuity to raise the amount in six years at 5 per cent., will be $230, the annual allowance for this item of expense.

If it should be alleged that many miles of the navigation may consist (as on the Lehigh and the Conemaugh) of slack water, procured by the erection of dams across the river, and the construction of a towing path along its margin, and other contingent works directed to this end, we say it appears to us but too probable that the encroachments of the water, drift, and ice, in freshets upon the channel, which must be kept clear for the passage of the boats, and upon the towing path, together with the deposites of mountain torrents putting into the river from that side, will, without any allowance for the repairs of the dams, be amply sufficient to exhaust that small amount.

An allowance should likewise be made, adequate to the insurance of the perpetuity of dams destined to form reservoirs, slack water, or for the direction of water into feeders, and the repair of the guard locks attached to them, as well as of the feeders. All canals have more or less of the works here named: some are more costly in their dams, some in their feeders, and others in their reservoirs; whilst some will be heavily burthened with a plurality, or even with the whole of these classes of works. What shall we assume for an average? Extended periods of duration, and the whole canal system, should here be averaged, commencing "eight years" after the introduction of the navigation, so as not to include the "extraordinary repairs" already alluded to, as being liable to happen within that term.

It will probably be a moderate estimate to assume the cost of these appendages at 10 per cent. of the entire outlay, and that, "barring accidents," the dams will last 20 years, but, in consequence of their exposed situation, the probability would be that, upon an average, they would have to be renewed every 12 years, or, that the expenses attendant upon them, would be barely covered by this assumption.

We shall assume $1,500 per mile as a medium sum to be provided in periods of 12 years for the amount of these charges, which will be rather more than ten per cent. of the entire outlay upon the least costly canals, whilst it will be less than 5 per cent. upon some others, and the cost per mile per annum of these appurtenances will be $94.

The next permanent source of expense peculiar to the canal system, that we shall mention, is that of the maintenance of waste weir, and the towing path across them. Wood as well as stone will generally enter, more or less, into the construction of the weir, and perhaps altogether into that of the bridge constituting the towing path over it. There will, generally, be one of these structures to each *level* or pool, but, if the level be long, more than one. We assume $125 per mile as the least amount for this item to be expended every 12 years, which is equivalent to about $8 per annum per mile.

The difference that will be found to exist in the cost of maintaining *accommodation* and road bridges across canals, beyond that which will be necessary across railroads, should not be excluded in the comparison. The facilities of passing across railways upon a level with their surface, both as respects private and public roads, are so great, that it may be said the railway offers scarcely any obstruction, and bridges, for this purpose, will seldom be required; whereas, upon canals, such bridges constitute a considerable item in the expenditures. Sometimes, however, the proprietor of the lands through which the canal passes, is paid a sum that disposes him to relinquish his claim to an *accommodation* bridge; but still the capital invested is enhanced in amount by that sum. Many farms, and all public roads that are to be kept up, and which the canal intersects, must have bridges over the canal.

We shall, for the present occasion, only assume that an outlay of $1,000 every 12 years, to sustain wooden bridges on three miles of canal, as the average of the excess beyond that required for similar expenditures in the railway system. This will equal $63 per annum, or $21 per mile per annum.

Supposing $500 to be required at the end of each term of ten years to sustain a set of lock-gates, we should estimate the cost of 66 sets, on 106 miles of canal, at $25 per annum per mile, and not $31 12 as calculated on page 171, Doc. No. 18, since an annuity of $31 12 regularly invested with the annual incomes in 5 per cent. stocks, would, at the end of ten years, when the money would be wanted, amount to $43,566, instead of $33,000, the sum assumed in the estimate for this item, as required upon the whole line of the canal. And it may here be remarked, that the estimates for the annual cost of a line of double railway, preferred in Document No. 18, p. 169–70, have been unduly swelled by adopting the same mode of calculation.

We shall here recapitulate the several items of expenditure per annum per mile, upon a canal, to the extent already calculated, with an allowance for superintendence and contingencies to the same amount as on the railway.

1. Repairing lock gates - - - - - -	$25
2. Incidental attention and labor upon the banks, tow-paths, ditches, drains, and culverts - - - -	125
3. Cleaning the canal of sediment, sand, gravel, and clay -	230
4. Repairing dams, feeders, and guard locks - - -	94
5. Maintenance of waste weirs, and towpath over them -	8
6. Renewing of bridges beyond that required on a railroad -	21
7. Superintendence and contingencies - - - -	25
Amounting to - -	$528

From an examination of the foregoing estimate, it will doubtless be noticed that we have not set down any thing to cover the contingency of a failure in walls, culverts, or aqueducts. To apologize for this omission, it may likewise be stated that, in making our estimate for the annual repairs upon the railway, we neither included walls, culverts, nor viaducts. These works were supposed to be well contructed in both cases. Had we entered upon the inquiry touching these structures, however, we should have been compelled to have awarded a balance in this respect against the canal system.

It is unnecessary, therefore, to look beyond the items of expense already enumerated, to see that the annual expenses attendant upon the repairs of a canal, may be expected to exceed those of a double railroad, even though wood, in lieu of stone, shall be used in the construction of the railway. [See doc. No. 5, hereto annexed, and already referred to.]

But the sum of $528, the amount of the foregoing estimate, does not include the whole of the yearly charge due to the maintenance of a mile of canal. It is the amount estimated to be required after the canal shall have been 8 years in use. It does not embrace any allowance for the "extraordinary repairs" which all new works of this description will certainly require, and which are supposed to cease within that term of years, in consequence of the acquired comparative permanency of the embankments. The great amount of "extraordinary repairs" and expenses to which a canal is subject when it is new, and, as a consequence, the length of time that elapses after it is declared to be finished, taken off the hands of the contractor and paid for, before it can be profitably used, will continue to be a peculiar characteristic belonging to this species of internal improvement, that should be brought into the account when a comparison is to be instituted between the relative merits of canals and railways, inasmuch as the latter are comparatively free from such expenses, and can be used, without delay, as soon as the rails shall be laid.

The experience of the canal system will not permit us to fix upon less than one year as the time that may be expected to elapse, after a canal is declared to be finished and is paid for, until its navigation becomes advantageous. This conclusion is corroborated by the instances which have occurred on the Pennsylvania canals, without looking further. See Report Pennsylvania Canal Commissioners, December 15, 1831.

The estimate stated on page 171, Doc. No. 18, for the annual repairs of the canals from Mauch Chunk to Bristol, and amounting to $156 12 per mile, as we have already stated, was made in the month of May, 1830. The calculator prudentially avoided swelling his estimate by the repairs that might take place during the first eight years. This estimate embraced 59¾ miles of canal along the Delaware, then in the course of construction by the State, but which was that season pronounced to be completed, and the water introduced in October of that year (1830.) This canal, however, has not yet been brought into profitable use, on account of the extensive repairs which had to be made during the year 1831, and amounting to $97,339 51, or $1,629 per mile.

The repairs during the year 1831 upon the following canals in Pennsylvania, viz. The Delaware division, (just mentioned,) Columbia line of the eastern division, Harrisburg line, including the Susquehanna, to lock at Barry's falls, North Branch division, West Branch division, Juniata division, Western division, and French creek feeder, being, in the whole 426¼ miles of canal, amounted to $353,644 58, or $830 per mile. (See Canal

Commissioners' report aforesaid.) And there has been at least a year lost in the use of these canals on account of the "untoward circumstances" attendant upon them. It is stated that this amount contains, besides the cost of "ordinary and extraordinary repairs," an allowance "for additional structures to render them [the canals] more perfect," but what this amount may be is not stated, nor is it material, since, as the imperfections were not foreseen, they could only be met and provided for in the repairs.

We will not take the result upon any one of these divisions of canal as an index of what may be expected to befal other canals; yet we think that an average upon 426 miles of canalling, situated in different and distant sections of the Commonwealth, should be regarded as data in completing the comparative estimates *commenced* in Doc. No. 18, but not *finished*, as we have shown.

Assuming, for the present occasion, the average cost of canals and their appurtenant works at $25,000 per mile, and seeing that their useful effects will, in general, be postponed a year after the time of their completion, it follows that the additional sum of $1,500, being the interest for a year, will be added to the capital, the interest of which, that is, $90, must therefore be provided for annually thereafter, and it may be considered as augmenting the annual repairs, inasmuch as it will originate in consequence of the canal requiring repairs.

It will next be proper to assign the amount of "ordinary" and "extraordinary repairs," that is, to determine how much of the $830 per mile, incurred in the repairs of 1831, was made up of the kind of repairs that are included in the *seven* items of the estimate which we have already made, (amounting to $528,) and the residue which will then be lacking to make up $830, will be for "extraordinary repairs" that will not occur after some years.

The canals being new, item No. 1, being for repairs of lock gates, will be *nothing;* No. 2 will be the full amount, $125; No. 3 will be *nothing*, since there has not been time for much alluvial deposite; No. 4, consisting of the repair of dams, &c., may probably have occurred to the extent of three-fourths of the amount of a permanent estimate, or $70; Nos. 5 and 6 *nothing*, for want of time for decay; No. 7 the full amount, $25. These items, being collected, make $220 as the probable amount per mile of the "ordinary" repairs, not consequent upon the weakness or defectiveness of new works of this description.

Consequently, $830, *minus* $220, leaves $610 as the amount per mile of the "extraordinary repairs" on these 426¼ miles of canal, in the year 1831.

On reference to the Canal Commissioners' report before referred to, page 22, (as printed by order of the Senate,) it will appear, that, of the sum of $353,644 58, the total amount of repairs, the Canal Commissioners assign $92,708 84 for "ordinary," and $260,935 14 for "extraordinary repairs," which result in $218, and $612, per mile, respectively. It will be seen that the allotment of $220, and $610, which we have just given, differs very little from that made by the Canal Commissioners.

Now, when it is considered that 195 miles of these canals were reported by the Canal Commissioners, on the 18th December, 1829, as finished, and therefore that nearly one-half of the entire extent had the advantage of the whole of the year 1830 to consolidate, it will be inferred that $610 per mile is not enough to cover the extraordinary repairs of the first year, inasmuch as it is to be presumed that the benefits of the repairs made in 1830

were effective in 1831, as limiting in degree the amount for that year. We shall, however, in this *comparative estimate* take these repairs at $610 for the first year and, instead of the apparently arbitrary assumption made on page 171, Doc. No. 18, that this description of repairs will extend through the term of "8 years' duration," shall limit them to 5 years, presuming that, during this period, the subsiding and consolidating of the parts will have been effected, or, at least, to such an extent, that the decreasing series of expenditures on this head will be covered in the respective years by 610, 488, 366, and 122 dollars. Discounting at 5 per cent. compound interest, the present worth of this series of payments is $1,638.

The interest of this sum at 6 per cent. per annum, or $98, will therefore be the perpetual annual charge estimated to flow from these "extraordinary repairs."

And the estimate for the amount of the repairs of a canal per mile, per annum, will finally be—

1, 2, 3, 4, 5, 6, 7. Items herein before estimated, and to accrue after due permanency is acquired, - - - - -	528
8. Interest of interest, accruing from delay in commencing profitable use, - - - - - - - -	90
9. Interest on present worth of extraordinary repairs made in the first few years, - - - - - - -	98
Amounting to - - - - - - -	$716

The capital at first expended will be augmented by one year's interest from the delay of the profitable use, beyond that to which railways are subject, by - - - - - -	1,500
It will also be augmented by the extraordinary repairs to which the canal is subject in the first few years, beyond those of the railroad, by - - - - - - - -	1,638
Total, - - - - - - -	$3,138

Hence if the construction when the canal is considered to be "finished," be $25,000 per mile, then the annual repairs per mile will be estimated at $716.

But should it be preferred to augment the capital by the beforementioned items, amounting to $3,138, then the capital per mile will be $28,138, and the repairs of canal, per annum, per mile, will be estimated at $528.

We can readily account, therefore, for the circumstance that the canals of New York which, when they were declared to be "finished," had cost only at the rate of $18,000 per mile, should, in the course of a very few years after, have been stated to have cost $21,000 per mile. For this purpose we have only to suppose the $3,138, or rather $2,718, (as the first cost was $18,000 instead of $25,000 per mile,) to have been further augmented to $3,000 by interests which the current tolls did not pay, or otherwise by greater repairs than are measured by the average we have adopted.

Having, in a concise and candid manner, endeavored to present such views of the subjects treated of as the present time and opportunity would allow, we shall annex a reference to the following additional papers, annexed hereto, and marked as follows:

No. 6. An abstract prepared by Wm. Woodville, superintendent of transportation on the Baltimore and Ohio railroad, containing an account of the number of passengers and tons of commodoties which were conveyed on that road, from the 1st of January to the 25th of February, both days inclusive, 1832, and tending to show not only the advantages to trade and intercourse to this particular road in the depth of a severe winter, when canal navigation was closed, but the great advantages which may be expected from the adoption of the railway system.

No. 7. An extract from an account of the Liverpool and Manchester railway, by Henry Booth, treasurer, Liverpool; republished by Carey & Lea, Philadelphia, 1831, containing "a general abstract" of the expenditures in the construction of that stupendous work, with "observations" thereon.

Frequent reference having been made, in Doc. No. 18, to the great cost of this road, without any allusion to the items and attendant circumstances, we have though it but just to annex them, and, at the same time, to protest against the endeavors which have been made, apparently to induce an impression of their inapplicability to this country. It is to be presumed, that, in the absence of special information, it would not be imagined that it could become necessary to pay £95,305 sterling, for land on about 30 miles of the route of a railway, or $14,000 per mile, independent of the land and buildings purchased at the two ends of the road, costing a further sum of $6,000 per mile. The expense incurred in obtaining a charter from Parliament, and for law, was £28,465, or about $4,000 per mile, yet such were the facts. Notwithstanding the enormous cost of this road, however, the dividends have been 4½ per cent. on the par value of the shares for each six months of the year 1831, or at the rate of 9 per cent. per annum; and it is said that the dividends could have been still greater, but for the reservation of a surplus with a view of forming a second tunnel under the town of Liverpool, at an estimated cost of £100,000.

Further observations in relation to the comparative merits of Canals and Railroads.

If it should be alleged that we have not been sufficiently definite in relation to the cost of construction, we would answer that, if our essay is liable to this charge, it is so, not from the want of the *will* to do ample justice to the subject, but rather from the absence of a sufficient number of examples in a new system of improvement scarcely yet introduced into the country.

We will, however, now offer our opinions a little more at length in relation to the cost of construction, having regard to the examples which we have, and to the facilities which we believe to exist.

The cost of a single tract of railway, laid with the use of sleepers and strong pieces of wood, the sleepers being 4 feet apart, and bedded upon broken stone, the dimensions and cost of the wood and iron being as in the estimate in the accompanying document No. 5, was, on the first division of the Baltimore and Ohio railroad, about $4,000 per mile, inclusive of the broken stone, labor, and contingencies. For the renewing of the perishable part of this structure, we have already furnished an estimate. It may be proper to say that, upon some of the divisions, the wood railway has cost more than upon the first division, owing, principally, to working too late in the season; to giving more than an average price for some of the materials

and labor, on emergencies; and to hauling some of the materials greater distances on the turnpike road than would have been necessary, but for a determination to open the road by a specified time. We are of opinion, therefore, that the average cost of such a railway in this country, may be set down at $8,000 per mile, since, in the interior, where wood is cheaper, the iron will be more costly. Such a railway would not only be suited to the use of horses as the motive power, but would likewise admit the use of light locomotive steam engines for the conveyance of passengers, moving within the following limits of velocity, that is to say: not exceeding ten miles per hour in curvatures of a radius of 1,000 feet or less, nor exceeding 15 miles per hour on the curved parts of the way, having a radius greater than 1,000 feet and less than 2,000 feet, and upon the straight parts; and on the curved parts having a radius greater than 2,000 feet, a velocity of from 15 to 20 miles per hour. It will be practicable, therefore, as much the greater part of the curvatures of a railway from Baltimore to the Ohio, may have a radius greater than 1,000 feet, to carry passengers at an average rate of 15 miles per hour, with the use of the locomotive engine; in which case the entire distance may be performed within 24 hours! With the use of horses as the moving power, the route to the Ohio would be performed in about 40 hours. The inclined planes across the Alleghany mountain would be worked with stationary steam engines at the rate of 10 miles per hour.

We have just given $8,000 as the average cost per mile of a double railway, upon which these performances may be made. It will now be proper to assign the probable average cost per mile of preparing the line for the reception of the railway. This will include the graduation and masonry; and we shall suppose the culverts and bridges to be of stone, with the exception of bridges over large streams, which may be of wood.

We shall suppose that few lines in this country of equal length will cost more than that part of the Baltimore and Ohio railroad from Ellicott's mills to the Potomac, a distance of 54½ miles. The cost of preparing this part of the line of that road, amounted to the average sum of $8,540 per mile. About 20 miles of this distance is in the granite reformation, the graduation of which, was rendered very expensive on account of the large masses of that material which had to be removed by blasting, whilst thorough cuts through projecting points of hills, 20, 30, and 40 feet in depth, had to be made, and new and extensive channels for the stream which occupied the narrow ravine formed; whilst the road was made to intersect and traverse the old channel in order to secure the proper curvature and direction. Upon the residue of the line, the excavations and embankments were heavy items, and included the graduation of four inclined planes at Parr's ridge. The quantity of masonry is likewise fully as great upon this line, as will be an average on most lines of equal length in this country. The work upon a large part of this line, was carried on with greater speed than comported with economy in the construction, in order that the road should be open for use to Frederick at the commencement of the winter. The last *letting* for graduation and masonry which was made, took place in June last, (1831,) to the extent of *twelve miles* including the planes at Parr's ridge, and the work did not fairly commence under this letting till after wheat harvest; yet with such energy was the work prosecuted, that a track of railway was completed to Frederick by the 1st of December last, at which time the road was formally opened and travelled from Baltimore to Frederick. On the twelve miles so quickly finished, the quantity of earth and slate rock re-

moved, in the formation of the road bed, averaged about 25,000 cubic yards to the mile, whilst the wages of laborers were enhanced from 75 to 100 cents per day.

These facts are stated to show that this part of the road cost more than an average amount for the same quantity and description of work under ordinary circumstances; at the same time they also demonstrate with what celerity a railway can be constructed.

As we proceed westward, the price of provisions and labor will become less. The reduction will probably amount to 25 per cent. by the time we arrive west of the Alleghany mountain. The rock to be encountered there will be principally freestone and other softer species of sand stone; the removing of which, will not be more than half as expensive as that on the Patapsco. For the same reason, the masonry will also cost much less. Under these views, it is highly probable that the same quantity in cubic yards of excavation and embankment, and the same quantity and extent of masonry and bridges that, between Ellicott's mills and the Point of Rocks, cost $ 8,540 per mile, would, west of the Alleghany, cost no more than $ 6,000. Adding the cost of a double railway laid with wood as before described, and the estimated cost of a double railroad per mile will be,

East of the Alleghany mountains - - - -	$ 16,540
West of do. do. - - - - -	14,000
And, in a comparatively level part of the western country, where timber is abundant, and to be used for the principal bridges, about - - - - - - -	$ 11,000

We shall now augment the prime cost of the railroad by a sum, which, we think, will be sufficient to compensate for restoring the embankments to their proper heights after settling, and for the removal of slips in the excavations. These will constitute the "extraordinary repairs" of the railroad, and will cease in a few years. Having endeavored to estimate this description of repairs for a canal, and at a rate that should only show the excess against the canal when compared with the railroad, it was not considered necessary, under that view of the subject, to estimate the extraordinary repairs to which a railroad is subject in its new state, from a want of solidity in its embankments. It is very evident that this description of repairs for a canal, will be greatly in excess; since, in the formation of the canal, on account of its greater width, and the depth below the berm, the excavations must be deeper than for the railroad, and the excavated banks in sidelong situations much higher. And, moreover, a slip of earth from the bank, after having fallen into the canal, will be much more expensive to remove from thence, than it would be to remove an equal quantity from the surface of the railroad. And, again, when a breach in the bank of a canal takes place, all the water upon that *level* to the nearest lock, each way, rushes through the breach, and, by enlarging it, cuts the embankment to its foundation, depositing the excavated materials in the bordering river, or, perhaps, upon the adjacent farm lands, to the damage of the proprietor; whereas no such breaches or devastations can be charged to the account of the railroad system.

The charge for the restoration of the embankments to the extent of their settling, as respects the railroad, can be estimated quite readily, as we know it, from experience, to be about 10 per cent., in case the embankment is of ordinary earth, and has been properly made.

Now we have supposed 25,000 cubic yards as about the average quantity

of embankment entering into the formation of a mile of railroad, one-tenth part of which may be considered to be of rock or of such consistency as not to decrease in volume; and there will remain 22,500 cubic yards, 10 per cent. of which, or 2,250 yards, have to be supplied, to counteract the effects of settling of each mile of the railroad. Eastward of the mountains, the cost of this removal may be taken at 25 cents per cubic yard, and westward at 20 cents. And, therefore, the allowance for this item will be, in the east, $563, and, in the west, $450. The greater part, and, in some instances, the whole of the earth required to raise the embankment to its requisite height, and from which it had receded, will be supplied from the redundant earth removed from the ditches in the cuts, at the prices stated. But as this may not happen in every instance, whilst, in places, more earth will have to be removed from the cuts than the repairing of the contiguous embankments will require, it may be proper to add 20 per cent., to cover the expense to arise from that difference, together with $160 in the one case, and $128 in the other, for adjusting the railway to the proper level at the same time that the embankments are raised.

The "extraordinary repairs" for each mile of a railway will, therefore, average $835 eastward, and $668 westward of the mountains. Supposing these repairs to take place proportionally, and in the same period as those upon the canal, and discounting for present money, these sums become $748 and $598 respectively, and the cost of construction will be further charged with these respective sums; or, otherwise, $45 in the one case, and $36 in the other, being the annual interests, will be set down as repairs per annum per mile. At present, we shall add these costs to the prime cost of construction in the two first stated cases; and, on account of the greater supposed favorableness of the country in the third case, we shall add to it only $500.

The cost of a mile of double railway, laid with the use of wood to support the rails, will, therefore, ultimately be,

1. Eastward of the Alleghany mountain, - - - -	$17,288
2. Westward of do - - - -	14,598
3. Westward of do and in the more level parts, where timber is abundant, - - - -	11,500

We now assert our opinion, that the average prime cost attendant upon the construction of canals and their appendages, upon grounds of similar natural formation, judging from what is understood to be the experience in this country, will, with but a medium number of locks and aqueducts built of cut stone, and no very expensive reservoirs, be as follows:

1. Eastward of the Alleghany mountain, - - -	$25,000
2. Westward of do - - - -	20,000
3. Westward of do and in the more level and favorable parts, - - - - - -	12,000

Upon the western section of the route of the Chesapeake and Ohio canal, extending from Cumberland to Pittsburg, a distance of 153 miles and $\frac{47}{80}$ of a mile, the cost of construction, as estimated by N. S. Roberts and A. Cruger, engineers, with a width of 48 feet, and depth of 5 feet for the canal, is $50,347 per mile. (See Doc. No. 18, page 126.) We feel confident that a double railway, upon the same route, would not cost the half of this amount per mile.

It is believed that the experience of New York, Pennsylvania, and Ohio, in relation to canals only 40 feet wide and 4 feet deep, will justify the assumption of these amounts; as it is probable that the canals constructed east

of the Alleghany, by the State of Pennsylvania, inclusive of dams, aqueducts, and basins, will have cost the rate here assigned, and it must be recollected that great reaches of the New York Erie canal occupy as favorable ground as do the canals of the State of Ohio, whilst provisions and labor were abundant and cheap. It must likewise be considered that, in the more recent formation of works of internal improvement, the competition, and, consequently, the cost, has been, and will probably continue to be, greater than when New York constructed her magnificent canals.

We have already endeavored to show that, upon an average, the ultimate cost of a mile of canal will exceed the cost when it is first declared to be "finished," by $3,138; and we gave our opinion that this would not be the absolute excess, but only the relative when compared with railroads.

Taking it, however, to be the absolute instead of the relative excess of the cost of a mile of a canal, when its embankments shall have become consolidated through time, beyond that of its first cost, and supposing the less cost of the canals in Ohio to require but the one-half of this allowance, without making any allowance for a western canal connected with the mountain region, since the damages upon the western division of the Pennsylvania canal, in consequence of freshets, have already, during the present winter been almost as great in amount as the reported repairs upon that division, which were made during the year 1831, then the relative cost of canals and railroads, such as we have described, will be as in the following table:

No.	Situation.	Railroad per mile	Canal per mile.
1	Eastward of the Alleghany mountain, -	17,288	$28,138
2	Westward of do -	14,598	23,128
3	Westward of do and when the facilities for construction are greater, -	11,500	13,569

We have already estimated the annual repairs of this description of railroads at $500 per mile, and of a canal that should be compared with it, $528 per mile. Adding the annual interest on the cost of a mile according to No. 1 of the foregoing table, and find the annual charge that is to govern the toll upon the railroad to be $1,537 28, and upon the canal $2,216 28. With a traffic amounting to 100,000 tons per annum, the toll necessary to repay these respective charges would be, upon the railway, 1 $\frac{537}{1000}$ cents per ton per mile, and upon the canal 2 $\frac{216}{1000}$ cents. Taking the cost of transportation per ton per mile upon the railway at $\frac{3}{4}$ of a cent, as we have estimated it, and upon the canal at $\frac{1}{2}$ of a cent, as some have estimated it to be on spacious canals, then the cost of both toll and transportation on the railway will appear to be 2 287-1000 cents per ton per mile, and upon the canal 2 716-1000 cents.

When 150,000 tons of commodities shall pass in a year, then the toll and transportation upon the railway will be 1 775-1000 cents per ton per mile, and upon the canal 1 977-1000 cents; but when 271,600 tons shall be the amount of trade, then the cost of toll and transportation will be the same on either, to wit: 1 316-1000 cents per ton per mile; and when the quantity of tonnage shall be greater than is here mentioned, then the entire cost of tran-

sit will be something less upon the canal than on the railroad. It will however occur only on great lines of intercommunication that even so large an amount of traffic as 150,000 tons per annum shall pass upon either a canal or a railway.

In the case of No. 2, the amount of annual tonnage that will be conveyed at an equal expense, both on the railway and the canal, is 216,160 tons; whilst, in the case of No. 3, it is only 100,856 tons; from which last we conclude that, in Ohio or any other place where the cost of a canal will average but $13,569 per mile, and a double railroad but $11,500, the canal will be preferable to the railway only when the tonnage in both directions shall exceed 100,000 tons per annum, and having regard only to the cost of the tolls and transportation. Other considerations attached to, and connected with either of the two modes of improvement, will, as a matter of course, be duly weighed, as well as the circumstance that the railway will be operative during the winter season.

These deductions, which award a slight preference in favor of the railway, regard only the conveyance upon it, as well as upon the canal, of heavy, bulky, and cheap articles. The instant, however, that we contemplate the conveyance of passengers, and the mails, or the transportation of light but costly articles of commerce, with regard to which it has often been truly said that "time is money," that moment the advantage must be awarded to the railway system in preference to the canal system, beyond the possibility of cavil. Moreover, these deductions flow from a contemplation of the use of horses alone, as the motive power, and it would be altogether unnecessary to reiterate in this place the advantages to result from the application to railways of the locomotive steam engine.

With regard to these estimates, it may be asked, how it comes that we have made the cost per mile only $17,288, when the average cost of the Baltimore and Ohio railroad, between Ellicott's mills and the Point of Rocks, will be $20,168 per mile, and from Baltimore to the Point of Rocks $27,128? We would answer that the cost of $20,168 includes a considerable length of railway, laid with granite instead of wood, whereas it will be observed that our estimate of $17,288 is for a railway constructed with sleepers and strong pieces of wood, as we have more than once described. This estimate, it is conceived, is a fair one for the average cost of such a railway. It is, however, but an average, and it may be expected that the actual cost will, in some instances, exceed, whilst in others it will fall short of this amount; principally, however, on account of variations in the cost of the graduation and bridging. With regard to the average of $27,128, which will be the actual cost on 67½ miles from Baltimore to the Potomac, it has, on more than one occasion, been stated to the public, that this amount was caused by the uncommon expensiveness of the first division, extending to Ellicott's mills, and indeed of the first seven miles only; and this was owing less to the inherent difficulties which nature really presented to the contemplation of the engineer than to circumstances connected with the interests of the improved parts of the city, and which claimed to be respected, by means of an approach to the city upon a high level, that greatly increased the expenses of the graduation as well as of the masonry. We cannot view this occurrence as having any claim to enter into the question of comparison between canals and railways, unless it should be agreed also to contemplate the probable cost of a canal on the 7 or even 13 miles, in which event we should expect a decided balance against the canal. A different view of this case, would be as unfair as it would be to

allege the cost of the tunnel under the town of Liverpool as an item inseparable from the railway system, when it is known that the docks could have been approached differently in another quarter, though not so agreeably to the interests of all parties. It is gratifying, however, to know, that, in conducting the railway to the basin, the Baltimore and Ohio Railroad Company have accomplished, on the surface of the streets of Baltimore, at an expense of from 15 to 20,000 dollars, what has cost the Liverpool and Manchester Railway Company $240,000 to secure, by passing *under* Liverpool!

It may also be expected that we should advert to the causes of the excess of the estimated cost of the "Alleghany portage railroad, in Pennsylvania," and of the "Columbia and Philadelphia railroad," beyond the average estimate which we have made. We did not expect this estimate of $17,288, to apply to that part of a railway that should include the inclined plane, and stationary engine system across the Alleghany mountain. It will have been noticed that, when upon this particular subject, our estimate for that section was $25,000 per mile, with a railway constructed as herein before described. The "Alleghany portage railroad" will be made to overcome an elevation of about 1,400 feet on the eastern side of the summit, and 1,171 feet on the western side, by means of stationary steam power, and when it is considered that it is to be laid exclusively of stone and iron, whilst the latter is of the heavy English rail, costing three times as much as the rail employed on the Baltimore and Ohio railroad, and that, besides a tunnel, some extensive bridges are contemplated, it may readily be conceived that this railway should cost $34,600 per mile, inclusive of the machinery. The "Columbia and Philadelphia railroad" is likewise to be laid with the expensive kind of rail just alluded to, upon cast iron chairs and stone blocks, and it also includes inclined planes and their machinery, and other very expensive work, and especially of bridges, having to traverse the country across the streams. This railway is estimated at $28,173 per mile. The construction is of the most expensive character, and it has been planned with a view to great permanency, and for the use of heavy locomotive engines.

We have founded our estimates upon that description of railway which will occupy an intermediate place in the system; being superior to that having but a single track, and inferior to that constructed exclusively of stone and iron, or to that which should be formed with heavier iron rails laid upon timber. We have done so, in part, because of the probability that is sort of railway will be extensively laid, and, in part, because its strength will be sufficient to withstand the action of common cars, and the lighter description of locomotives; but with a less velocity than is attainable, or than will be found to be expedient upon some lines of railway that have been, or that will be, projected; yet, allowing of a speed altogether sufficient for the general purposes of trade and intercourse, decidedly superior to canals for the conveyance upon it of passengers and goods of the comparatively light and valuable descriptions, and not inferior to them for the conveyance of commodities of the more bulky and heavy character, especially as the operations upon it will not be interrupted from drought, nor, in any material degree, from frost and snow.

It will be seen that the estimate for the annual repairs of a mile of railway, laid with wood, is about the double of that laid with stone sills, when the quantity of iron in the rail is the same in each case; that is, the difference is $250 per annum. When, therefore, in the construction, or in the repair, after the wood shall decay, the substitution of stone sills for wood,

shall not involve an expenditure in the construction or repair, as the case may be, beyond that of the use of wood that will last 12 years, to an amount that will produce an interest of $250 per annum at 5 per cent., or $5,000 per double track, then it will be cheaper to use stone than wood.

It follows from thence that the toll will be as moderate upon a railway laid exclusively of stone and iron, as it will be when wood shall be used in the construction; that is, when the railway alone, exclusive of the graduation and masonry, shall cost in the one case $13,000 per mile per double track, and in the other $8,000. It may be expected that, eastward of the Alleghany, the stone sill and iron railway will cost from $12,000 to $16,000 per mile of double track, exclusive of the graduation and masonry, according to the quality of the stone and the local facilities. We conclude, therefore, that the advantages of the use of stone sills, instead of strong pieces and sleepers of wood, in the construction, should, in every case, be a subject of due consideration and calculation as to the difference of expense; which should not be allowed to exceed $5,000 per mile, as we have stated.

These remarks regard a railway upon which the motive power shall be horses, stationary steam engines, and the lighter description of locomotives that shall not move with high velocities. If, however, it shall be intended to use the more powerful locomotives, or to employ a velocity that shall reach to 15, 20, and, occasionally, to 30 miles per hour, it is conceived that the stone sills must be employed, or the railway must be laid according to the English plan, as adopted on the "Columbia and Philadelphia railroad," or, lastly, it may be laid upon wood, by using iron rails that shall not weigh less than 100 tons to the mile of double track, whilst the wood may be increased somewhat in quantity. Of these methods, we lean in favor of the stone sills, or the wood, in preference to the English method of stone blocks and cast iron chairs, inasmuch as we believe that the object will then be attained at a less expense in the construction and repairs. The adoption of wood, however, in the latter case would not be preferred to the stone sills, if the latter were accessible at a sufficiently reasonable amount of expense.

The kinds of railway last adverted to, will vary, in expense of construction, from $12,000 per mile of double track, up to $20,000 per mile, exclusive of the graduation and masonry, according to the degree of permanency given to the work and the quantity of iron employed. It is probable, however, that a railway constructed with a view to the use of locomotive engines weighing six tons, to move with the higher velocities, so as to average 15 and 20 miles per hour, can be constructed for from $15,000 to $16,000 per mile, exclusive of the graduation and masonry.

A railroad constructed in this manner, and for these purposes, may be expected to cost from $25,000 to $30,000 per mile, when the graduation and bridging shall be of a medium character in point of expense; but may be expected to ascend to 40, 50 or 60 thousand dollars a mile, or even more; according to the obstacles to overcome in the character of heavy excavations, embankments, viaducts and tunnels.

Previous to engaging in the construction of any considerable work of intercommunication, but more especially of a railway of the latter very expensive description, the project should be well weighed in all its attendant aspects of probable expense and income.

We have not undertaken to institute a comparison between a canal and a railway of the latter description, inasmuch as this kind of railway is planned

and executed to accomplish effects in time and space, of which the canal system has furnished no example, and for which it is, beyond question, wholly inadequate.

Respectfully submitted.

J. KNIGHT.

N. B. The estimate [appended, marked No. 87.] recently made upon the route between Baltimore and Washington, is for a railroad of the character here contemplated and just described.

No. 1.

CHAP. IX. WOOD'S TREATISE, ED. 1831.

Comparative performances of motive power on Canals and Railroads.

The existing agitation of the public mind respecting the relative utility of railroads and canals in the transit of goods from one place to another, renders it a subject of proper inquiry, to ascertain the relative performances of the different kinds of motive power upon those two species of internal communication.

I shall, therefore, give a brief comparison, founded on the foregoing deductions of the different kinds of motive power upon railroads, with the performance of horses, by the present mode of canal navigation.

Not having had an opportunity, from my own personal observation, of ascertaining, with sufficient accuracy, the weights which a horse will drag in a boat upon a canal, I shall be obliged to have recourse to the reports of those engineers, whose practice, in that line, has enabled them to obtain the necessary data.

Mr. R. Stevenson, of Edinburgh, in his report on the Edinburgh railway, in 1818, states: "Upon the canals in England, a boat of 30 tons burden is generally tracked by one horse, and navigated by two men and a boy; on a level railway, it may be concluded that a good horse, managed by a man or lad, will work with eight tons: at this rate, the work performed on a railway by one man and horse, is more than in proportion of one-third of the work done upon the canal by three persons and a horse;" and Mr. Stevenson, in his calculations afterwards, assumes the power of a horse, upon a good railway, equal to ten tons.

Mr. Sylvester, in his report on the Liverpool and Manchester railway, gives twenty tons as the performance of a horse upon the canal, travelling at the rate of two miles an hour.

The variation of these two statements may have arisen from the observations being made on canals of different widths. Mr. Stevenson, in another report, states, that the striking difference between the draught of horses on coming out of a narrow canal into a more capacious one, induced the reporter to give the subject particular attention; and, by means of experiments made with the dynamometer, so far as he had an opportunity of carrying the experiments into effect, the difference appeared to be at least one-fifth in favor of the great canal.

We have been favored, by Mr. Bevan, with some experiments and observations on the force of traction, with different loads and velocities, on canals.

The resistance was ascertained by a spring dynamometer attached to the towing rope. The length of the boat was 69.5 feet, breadth 6.92 feet. The correct transverse section of the canal was not obtained, but was from 90 to 100 feet; the immersed part of the boat being about 19 feet, or one-fifth of the channel.

The force of traction required to move this boat, loaded with 23.77 tons, at a mean velocity of 2.45 miles an hour, was, on an average of fifty-four observations, 79.5 lbs.

With this load, Mr. Bevan remarks, one horse generally travelled 26½ miles a day.

The same gentleman has also favored us with the following experiments made on the Grand Junction canal at Paddington:

Transverse section of canal 142 feet
Loaded boat - - 17.2

a weight of 72 lbs. acting over a pully, drew the empty boat at the rate of 3.45 miles an hour.

A weight of 77 lbs. acting in a similar way, produced a medium velocity of 2.5 miles an hour when the boat was loaded with 21 tons of cast iron.

And all circumstances the same as the last experiment, it required a weight of 308 lbs. to produce a mean velocity of 3.83 miles an hour.

Mr. Bevan adds, "The length of the towing line may be considered 98 feet, and the mean distance of the boat from the towing-path, 20 feet. From this experiment, considering that the canal, in that part, was of greater area than it is upon an average, it may be inferred that, to maintain a velocity of four miles an hour, with a loaded boat, it would require the aid of four horses, provided the safety of the banks would allow; but as the canal is now formed, it would not be capable of withstanding the waste produced by such a velocity."

Mr. Chapman (Canal Navigation, page 73) states, that he observed a boat, 8 feet width of floor, 10 feet width of water line, 50 feet extreme length, loaded with 14 tons, and drawing 2.25 feet of water, dragged against a stream, the velocity of which was 5½ miles an hour, with 28 trackers, and three men in the boat, pulling it on, and yet it did not advance more than a quarter of a mile an hour.

Mr. Smeaton's estimate was, 22 tons burden, from 2 to 2½ miles an hour, with one horse.

Mr. James Walker, of London, made some experiments in the London docks on the relative resistances at different velocities, the result of which he communicated to the Royal Society, (May 31, 1827) which being very conclusive, and conducted with great care, we give an abstract of them. (Note L. Appendix.)

The result of these experiments was, that the resistance increased in a greater proportion than the duplicate ratio of the velocities, the respective resistances being as follows:

Velocity in miles an hour.	Observed resistance in lbs.	Resistance calculated in duplicate ratio of the velocity standard.
2.529	9.41	
4.529	42.59	38.11
3.871	28.07	22.07

Some experiments, subsequently made, on the Forth and Clyde canal, are said to have produced a contrary result at high velocities. We have not

seen any official account of these experiments, but it is said that, at low velocities, the resistance was found to correspond with that previously known; but, on pushing the horses at a greater rate of speed, the force of traction diminished, the waye at the bow of the boat disappeared, and the agitation of the water in the canal became comparatively trifling.

We confess we are somewhat sceptical as to the *practical* result of these experiments, and, at the present eventful period in the *life* of canal conveyance, should think that such an important fact ought not to lie dormant. The welfare, and, indeed, almost the existence of so many millions of property depending upon the inquiry, calls loudly for the substantiation or disproval of such important results by a series of incontrovertible experiments.

Whatever may have been the *experimental result*, we had an opportunity lately, on a visit to Edinburgh, of observing the *practical result* arising out of these experiments.

A boat, constructed of that form which was found to produce the least agitation of the water in the canal, has been applied to convey passengers from Edinburgh, by the Union, and then the Forth and Clyde canal, to Glasgow.

The boat is of great length, and narrow, and, in passing at the rate of $6\frac{1}{3}$ miles an hour, or 1,120 yards in 366 seconds, the wave, following the boat, was very considerable; so great, that we observed, at one of the bridges, the water washed over a height of masonry $19\frac{1}{2}$ inches above the ordinary level of the water in the canal.

The boat was dragged by three horses attached to the towing line, with a boy riding a poney to drive them. The distance, travelled upon the Union canal, is $31\frac{1}{2}$ miles, and, in that distance, there are six sets, or changes of horses; the same horses returning the same distance back.

This will give the power required equal to that of three horses travelling 10.5 miles per day; the boat carrying about 60 passengers.

The horses seemed much distressed by the draught, the action being that of a continual dead and unrelaxing effort. Since this, at the commencement of the frost in December, the boats have been laid aside, and are not, it is said, to be resumed until an iron boat of a better form be built.

Suppose the useful load of this boat equal to 5 tons, then $\frac{5 \times 10}{3} = 16\frac{2}{3}$ tons, conveyed one mile, will be the daily performance of a horse on a canal at seven miles an hour. And if we take 24 tons of goods, conveyed 20 miles, at $2\frac{1}{2}$ miles an hour, we have the relative performance at $2\frac{1}{2}$ and 7 miles, as $16\frac{2}{3} : 480$.

But we have the relative effort of horses at $2\frac{1}{2}$ and 7 miles an hour as $102 : 384$, whence $\frac{16\frac{2}{3} \times 384}{102} = 62.5$; and, therefore, the relative performance of horses dragging boats on canals, at $2\frac{1}{2}$ and 7 miles, is as $62.5 : 480$; the resistance, being equal to the duplicate ratio of the velocity, would give $62.5 : 490$.

According to the experiments of Messrs. Bevan and Walker, the resistance should have afforded results greater than the duplicate ratio of the velocities; but we must observe that those experiments were made with the *same* boat; whereas the results above is from *another* boat than that which was used for slow rates of speed, and of a construction more adapted for diminishing the resistance.

We are, therefore, we trust, justified in concluding that when the most suitable form of boat is adopted for the particular load it has to carry, the

resistance of boats on canals, is, at least, equal to the duplicate ratio, or square of the velocity.

The diagram III., page 195, will, therefore, represent the resistance at the different velocities; and the following table will show the relative quantity of work which a horse is capable of performing by dragging boats on canals, and carriages upon railways; assuming that the maximum of useful performance daily on the former is equal to 480 tons of goods conveyed one mile; and, upon the latter, 160 tons conveyed one mile; making the relative performances as 3 : 1.

TABLE XIII.

Velocity in miles an hour. Maximum rate.	Useful weight conveyed in tons.	Distance in miles.	Useful effect in tons conveyed 1 mile.	Number of horses required on canal.	Number of horses required on railway.	Ratio of performances of horses on canals and railways.
	24	20	480	1.	3	1 : 0.33
3	24	20	480	3.4	4.5	1 : 0.75
4	24	20	480	8.2	6.3	1 : 1.3
5	24	20	480	18.	8.7	1 : 2.7
6	24	20	480	31.8	10.6	1 : 3.
7	24	20	480	53.6	13.0	1 : 4.1
8	24	20	480	85.6	16.	1 : 5.3

From this, we find that, when the rate of speed is about two miles an hour, the quantity of goods which a horse can convey upon a canal, is three times that which the same horse can convey upon a railroad. And that, when the velocity on each is about 3½ miles an hour, the resistance of the canal increasing as the square of the velocity, while that of a railroad remains the same—the two become equal; and a horse is then enabled to drag as much weight upon a carriage on a railroad as in a boat on a canal. When the velocity is further augmented, then the disproportion becomes greater, and a much heavier load can be conveyed on a railroad, with the same quantity of motive power, than can be done on a canal.

If, therefore, the rate of tonnage on a canal, arising from the cost of forming, and keeping it in a state of active use, together with the cost of boats, be not greater than the tonnage required to form and keep a railroad in repair, and also the carriages by which the goods are conveyed; then the relative economy, at different rates of speed in the transit of goods upon canals and railroads, will be represented by column 7 of the preceding table. But, as in general, the formation of a canal costs much more than the formation of a railway, and the annual charges of keeping the boats, towing paths, and bridges, &c., in repair, is also considerable, if those expenses be as much greater on a canal than upon a railroad, so as to compensate for the extra advantage of the canal in the greater quantity of goods conveyed at a slow rate, then their relative utility will assume a different value, and the railway, requiring a less investment of capital, and less annual charges, may be superior, and more economical, even at the lowest and most advantageous rate of motion upon canals; and, where facility or expedition of transit is an object, then, at the more rapid rates of speeds, the railway will be proportionably superior.

These elemental considerations being, however, matters of calculation, where every instance may present a different conclusion, and being dependent upon all the various concomitant circumstances incident to each particular case, cannot, in a work like this, be made the subject of even conjecture. We have endeavored to furnish all those data which appeared general, and which applied to the two modes in conjunction with each other, in a practical and general point of view; and it must be left to those pursuing the inquiry into all the circumstances of each particular case, when they come into competition with each other, to judge, from the individual characteristics of each mode, which of the two is preferable.

When it becomes the subject of discussion which of the two modes is to be adopted, it assumes rather a different shape than when a railroad, the transit on which is performed by horses, is to enter into competition with a canal already formed.

In the latter case, the canal proprietor commences with considerable advantage, by the additional quantity of goods which a horse can drag at a slow pace upon a canal, where, perhaps, a little loss of time may be no object; and the canal proprietor may, even with his great investment of capital, by reducing his rates of tonnage extremely low, be enabled to compete successfully with a railway.

For, although a horse may, when travelling at the rate of four or six miles an hour, convey a greater quantity of goods upon a railway than when employed in dragging goods at the same velocity upon a canal; yet still a horse cannot drag more goods at the rate of four miles an hour upon a railway than he can at two miles an hour upon a canal; for, in no case, does the greatest quantity of work that a horse can do at the most beneficial pace on a canal, reach below three times that which a horse can do at any pace upon a railroad.

For the conveyance of passengers, or where the transit of any species of goods may require a celerity of four miles an hour, then railways become, unquestionably, more economical than canals; but if the question be the abstract performance, or quantity of goods to be transported from one place to another, without reference to speed, then the *quantity of work* done by a horse on a canal will always be three times that which he is capable of doing on a railway. The comparative expense arising from the extra interest of capital, and the annual charges and maintenance of a canal, may reduce this proportionate performance near to an equality; or, if the one compensate for the other, then, perhaps, the less investment of capital in a railroad, and the greater certainty of transit, may make it superior to a canal. But, unless the disparity of cost is great between a railroad entering into competition with an existing canal, or unless some extraordinary circumstances in the nature of the traffic occur, it may be difficult to say, when *horses* are the motive power on each, which is superior.

There is one very important property in a railway which gives it a great advantage over a canal, viz. the range of undulation which its nature permits; a straighter and shorter line can mostly be made between one place and another, which, from the necessity of having canals always perfectly level, or, at least, that level only broken at certain intervals by the occurrence of locks, occasions, frequently, a difference in distance of considerable magnitude; and this, in many instances, may diminish the comparative cost of transporting goods, and give a superiority to railroads.

And, again, in many cases, where the principal part of the goods are to

be conveyed in one direction, by a proper inclination of the railway, the weight of the goods conveyed, or quantity of work done, may, in some instances, be considerably augmented, without presenting a greater average resistance than previously stated, when the relative performance upon railroads will be proportionably increased. We have a very striking proof of this in table 5, of the weight which a horse can drag, upon certain inclinations of road, when the train is descending. On 1 in 250, the gross weight is 28.44 tons, an increase of performance in the ratio of 28.44 : 12, which cannot be taken advantage of by a canal; as, in that case, locks would be required, which would diminish, rather than increase, the performance.

Having thus given a few hasty remarks on the comparison of railroads with canals, in the use of animal power, we shall now give a brief comparison between the use of mechanical power on railroads, and animal power on canals; and here, as in every other case where the two species of action come in competition, we shall find the mechanical power outstrip the animal in general economy.

TABLE of the relative performances of Horses dragging boats on Canals, and Locomotive Engines dragging carriages upon Railroads. The former supposed to be without locks, and the latter horizontal.

TABLE XIV.

Velocity in miles, per hour.	Useful weight conveyed, in tons.	Distance, in miles, being that which a horse travels in a day.	Time, in hours, occupied by horses in travelling 20 miles, at the respective velocities of column 1.	Number of horses required to perform the work on a canal, from table xiii.	Distance, in miles, which a locomotive engine, on a railroad, would travel in the time of column 4.	Ratio of distance traversed in the same time by locomotive engines on a railroad, and horses dragging boats on a canal.	Ratio of performance of horses on canals, and locomotive engines on railroads, in the time of column 4.
Max.rate	24	20	8	1.	120	6 : 1	1 : 6
3	24	20	$6\frac{2}{3}$	3.4	100	5 : 1	1 : 17
4	24	20	5	8.2	75	$3\frac{3}{4}$: 1	1 : 30
5	24	20	4	18.	60	3 : 1	1 : 54
6	24	20	$3\frac{1}{3}$	31.8	50	$2\frac{1}{2}$: 1	1 : 80
7	24	20	$2\frac{6}{7}$	53.6	$42\frac{6}{7}$	$2\frac{1}{4}$: 1	1 : 120
8	24	20	$2\frac{1}{2}$	85.6	$37\frac{1}{2}$	$1\frac{8}{9}$: 1	1 : 175

From this table, we find that a locomotive engine, effecting a constant average velocity of fifteen miles an hour, will, in ten hours, on a railroad, perform the work of six horses, employed in dragging goods at the rate of two miles an hour upon a canal; and, as this rate of speed on a canal is that when the performance of a horse is a maximum, we derive the conclusion—*that, so long as the expense of one locomotive engine does not exceed that of six horses and their attendants, then goods can be conveyed with the same expenditure of motive power, at fifteen miles an hour, upon a railroad, that they can be conveyed at two miles an hour upon a canal.*

We have elsewhere stated that, in general, one locomotive engine may be estimated to cost as much as four horses; but the comparison was made with horses upon railroads, where one attendant to each horse is sufficient. On canals it will be different, as the attendants upon each horse and boat are generally three; the relative cost of locomotive engines will, therefore, be diminished, and their utility, in comparison with horses on canals, proportionably increased.

But this is not the only benefit resulting from the application of steam power to railways, viz. that goods are conveyed with the same expenditure of motive power on a railroad, at the rate of fifteen miles an hour, that goods can be conveyed at the rate of two miles an hour upon a canal.

If it be attempted to augment the velocity on a canal to three miles an hour, then one locomotive engine on a railroad will, in six hours and two-thirds, perform the work of seventeen horses on a canal; and if the velocity be further increased to four miles an hour, then, in five hours, the locomotive engine will perform the work of thirty horses; and, as often as these *times* are repeated, a similar ratio of performance will be accomplished.

We have a very conclusive illustration of this in the instance of the *fly-boat* on the Union canal: supposing it loaded with sixty passengers back and forwards, the $31\frac{1}{2}$ miles requires eighteen horses. Upon the Liverpool and Manchester railway, nearly the same distance, an engine traverses, twice a day, with 120 passengers at a time=120 miles. Therefore $\frac{120 \times 2}{60} \times 18 = 72$ horses. From which we find that an engine, half loaded, performs the work of 72 horses, conveying passengers on the railroad at a rate of transit more than double that on the canal.

This is sufficient to show the utter impracticability of attempting a competition between canals with horses, and railroads with locomotive engines, in the conveyance of passengers. It follows, from this, that the only superiority existing in any part of the economy of canals, and that wherein a transient advantage over railroads occurs, when animal power is employed, and which consists in the less resistance opposed to the motive power in transporting heavy goods at a slow pace, is superceded by the application of machinery to railways. And this result may be expected whenever, as previously stated, the nature of the work permits the application of mechanical power in the one case, and it is brought into competition with animal labor in the other.

These observations of the relative performances, with respect to work on railroads and canals, apply to the motive power only.

If the formation and annual charge of a canal exceed that of a railroad, then a further increase of advantage is produced in favor of railroads: on the contrary, if the balance is in favor of a canal, then it will become a question, whether the additional celerity in the transit of goods by a railroad, will compensate for any additional cost of the railway? In general, the difference of cost, both in the formation and annual charges, is presumed to be in favor of railroads, (see note M,) and, if any judgment can be formed from a comparison of the tonnage upon the various canals in the different districts of England, and that on railroads, the presumption appears nearly indisputable. (See note N.)

The trifling injury done to the road by the action of the locomotive engine, considerably enhances its value, by diminishing the charges of tonnage for annual repairs, which, added to the less investment of capital required

in the formation of a railroad, excites reasonable expectations of a very important change in the economy, and also celerity of internal communication.

In the above disquisitions, canals have been compared with railways in their most favorable state, as being without locks; any variation from this, will throw the balance more in favor of the latter; any deviation in the line of a canal from the horizontal, must be overcome by locks, which are productive of delay; whereas, in a descending line, especially when the trade is in that direction, an incaease of effect takes place.

In these disquisitions, we have a decided superiority of railroads, both in point of economy and despatch, in the conveyance of heavy goods over canals. In the conveyance of light goods, or passengers, no practical comparison can be made. Canals, after between 70 and 80 years' experience, seem incapable of being applied to those purposes. Railways, on the contrary, seem indisputably the best and most economical for all the purposes of internal communication and traffic, for light or for heavy and bulky goods, as well as for celerity of intercourse, the most rapid ever yet effected.

Taking all these circumstances into consideration, it can no longer be questioned which of the two modes is superior: the example of the Liverpool and Manchester railway, where it has been proved that, with an expenditure of capital of the greatest magnitude in overcoming difficulties which, perhaps, will never again present themselves, the conveyance of passengers alone was sufficient to realize a remunerating price to the company.

Canals being incapable of adaptation to the celerity of transport requisite for such purposes, are, therefore, deprived of a source of revenue the most lucrative; in a few, and, perhaps, only in a very few instances, can therefore canals be brought into a comparison with railways.

And when we look at the rapid improvement which the latter have undergone within so short a period, the improvements which are still in progress, and which the ingenuity of that combination of talent now so powerfully directed towards them cannot fail of bringing to the highest state of perfection, we are led to expect the most important results in the economy and celerity of commercial intercourse.

It will not, perhaps, be necessary, in a work like this, to explain, at greater length, the relative merits of canals and railroads. Local circumstances may effect general results, but, unless other causes transpire than the simple abstract question of the two modes in comparison with each other, we have, by the application of mechanical power to railroads, the advantage of a less investment of capital, and also a saving, by the motive power, which, combined with the celerity of despatch, must prove of infinite importance to commerce.

No. 2.

TABLE X. WOOD'S TREATISE, ED. 1831.

Gross load, in tons, which a locomotive engine, capable of taking 30 tons, at 15 miles an hour, will drag at the undermentioned velocities, in miles an hour.

Inclination of plane.	10	11	12	13	14	15	16	17	18	19
Level -	53.4	51.81	45.	39.23	34.28	30.	26.25	22.94	20.	17.36
1 in 4480 -	50.85	49.35	42.57	37.35	32.62	28.57	24.97	21.82	18.97	16.5
2240 -	48.51	47.1	40.87	35.62	31.12	27.22	23.85	20.85	18.15	15.9
1120 -	46.5	45.03	39.07	34.05	29.77	26.02	22.8	19.95	17.32	15.07
1000 -	43.56	42.3	36.75	32.02	27.97	24.45	21.45	18.7	16.27	14.17
900 -	42.9	41.7	36.3	31.57	27.6	24.15	21.15	18.45	16.12	13.95
800 -	41.7	39.9	35.15	30.6	26.77	23.4	20.47	17.85	15.6	13.5
700 -	41.25	39.	34.05	29.7	25.95	22.73	19.87	17.32	15.07	13.12
600 -	39.	37.8	32.85	28.57	24.97	21.9	19.05	16.72	14.55	12.67
500 -	37.05	36.	31.2	27.22	23.77	20.85	18.22	15.9	13.87	12.
448 -	35.61	34.5	30.	26.1	22.87	19.7	17.47	15.25	13.27	11.55
400 -	33.75	33.15	28.8	24.37	21.97	19.2	16.8	14.7	12.75	11.1
350 -	32.7	31.56	27.37	23.92	20.85	18.25	15.97	13.95	12.15	10.5
300 -	31.44	29.76	25.8	22.53	19.65	17.17	15.07	13.12	11.47	9.97
250 -	28.2	27.36	23.77	20.7	18.57	15.82	13.87	12.07	10.57	9.15
200 -	25.11	24.36	21.22	18.45	16.12	14.1	12.37	11.05	9.37	8.17
150 -	21.36	20.7	18.	15.6	13.65	12.	10.5	9.15	7.95	6.93
100 -	17.55	17.02	14.77	12.9	11.25	9.82	8.62	7.5	6.58	5.71

Table X gives the performance of a locomotive engine, at the rate of 10 miles an hour, 53.4 tons; and we are convinced, from experiments made since the calculation of that table, that we are quite within their powers. An experiment, with the "Planet" engine, gives 75 tons gross conveyed from Liverpool to Manchester (30 miles) in 2 hours and 54 minutes. (See Appendix, Note E.)

We shall, however, take the performance in the table at 12 miles an hour, equal to 45 tons, and continue the comparison for 8 hours, which will make, at 2½ miles an hour, the horses accomplish their day's work of 20 miles, and the engine 96 miles in that time.

The following table will then show the respective performances:

TABLE XII.

	Velocity in miles per hour.	Load taken in tons.	Distance travelled per day.	Effective performance in tons conveyed 1 mile	No. of horses equal to one locomotive engine.
Locomotive engine	12	45	96	4,320	
Horses - -	2½	12	20	240	18
	10	3 3-8	13	43.8	98

We have given two tables, one table X, on the supposition that 30 tons moved at 15 miles an hour, is the load, and the other (table XI,) one-third more, or 40 tons moved at the same rate.

On long lines of road, we may calculate upon a load equal to the reisistance of 30 tons upon a level being taken, calculated upon the *average inclination* of the whole line: provided that any short undulations, which may occur, do not present a resistance greater than the power of adhesion of the wheels, or greater than given in table XI.

The latter table will, therefore, show the load which may be overcome upon any short undulations, and the velocity which the engine can move with such loads; and we have carried the calculations of those tables farther than the load which the adhesion of the wheels can overcome.

That the engines are capable of effecting such a performance as that shown in table XI, will appear from a calculation of the powers of the "Planet" engine. The cylinders are 11 inches diameter; length of stroke 16 inches; area of cylinders = 190 inches, which, moved through 32 inches in each revolution of the wheels, = 6,080.

The diameter of the wheels is 5 feet; circumference 188.4; the resistance of 40 tons, is 400 lbs.; whence $188.4 \times 400 = 79{,}360$; therefore, $\frac{79310}{6080}$ = 13 lbs. per square inch upon the piston effective pressures, to overcome a resistance equal to 40 tons, moved at the rate of 15 miles an hour; which, with steam of the elasticity of 50 lbs. per square inch, is an effective pressure of 26 per cent—the number of strokes per minute being 84; velocity of piston 224 feet per minute. We shall now ascertain, if the boiler is capable of generating a sufficient quantity of steam, to keep up an adequate supply at 50 lbs. pressure per square inch.

The area of the two cylinders is 6080×84 strokes per minute, = 510.720 cubic inches of steam expended every minute. We find, from table IX, that the "Arrow," whose powers of generating steam is not equal to the "Planet," evaporated 275 gallons per hour, or 4.80 gallons per minute; which will give about 501,328 cubic inches of steam, at 50 lbs., or 510,720 cubic inches, at 49 lbs., increasing the effective pressure from 26. to 26.5 per cent. We have previously found that these engines are capable of yielding an effective power of upwards of 30 per cent. of the pressure on the piston.

We thus see that those engines are not only capable of effecting a performance equal to that in table XI, for short distances, or over casual undulations; but that, with a power of evaporation equal to 275 gallons per hour, they will be capable of constantly keeping up that performance.

Note E.

"On Saturday last, (4th December, 1830,) the 'Planet' engine, Mr. Stevenson's, took the first load of merchandise which has passed along the railway from Liverpool to Manchester. The team consisted of 18 carriages, containing 135 bags and bales of American cotton; 200 barrels of flour; 63 sacks of oatmeal, and 34 sacks of malt, weighing, altogether, 51 tons 11 cwt. 1 quarter.

To this must be added the weight of the wagons and oilcloths, viz. 23 tons 8 cwt. 3 quarters; tender, water, and fuel, 4 tons; and 15 persons on the team, 1 ton; making a total weight of exactly *eighty tons*, exclusive of the engine about 6 tons.

The journey was performed in 2 hours and 54 minutes, including three stoppages of five minutes each, (one only being necessary under ordinary circumstances,) for oiling, watering, and taking in fuel; under the disad-

vantage also of an adverse wind, and of a great additional friction in the wheels and axles, owing to their being entirely new. The team was assisted up the Rainhill inclined plane, by other engines, at the rate of 9 miles an hour; and descended the Sutton incline at the rate of 16½ miles an hour. The average rate, on the other part of the road, was 12½ miles an hour, the greatest speed on the level being 15½ miles an hour, which was maintained for a mile or two at different periods of the journey."—*Liverpool paper.*

"The journey between the two places was, on the 23d November, performed by the 'Planet' engine in 60 minutes, including two minutes, the time employed in taking in water on the road as usual.

"The motive for performing the journey, was, that the engine had been engaged to bring up from Manchester to Liverpool some voters for the election; and, by some cause or other, the time of setting out was delayed, rendering it necessary to use extraordinary despatch in order to convey the voters to Liverpool in time."—*Liverpool paper.*

"The engines have conveyed about 50,000 passengers, and have traversed a distance of 28,620 miles, or 954 trips from Liverpool to Manchester and back, from the 16th of September to the 7th December, inclusive; during which period there have only been eleven instances of the journey exceeding by half an hour the time fixed for its performance."—*Liverpool paper.*

No. 3.

Office of the Baltimore and Ohio Railroad Company,
January 27, 1831.

Gentlemen: In compliance with your request, under date of the 19th instant, and in obedience to an order of the House of Delegates, passed on the 11th, requiring "the Committee on Internal Improvements to inquire into, and report the relative expense, benefits and facilities of constructing railroads and canals, with a view of ascertaining to which of those means the funds of the State can be most beneficially applied;" I now enclose a communication, illustrative of these several subjects, from the chief engineer of the Baltimore and Ohio Railroad Company.

And am, very respectfully, &c.

P. E. THOMAS, *President,*
Baltimore and Ohio Railroad Company.

To the Committee on Internal Improvements,
House of Delegates, Annapolis.

Engineer's Office of the Baltimore and Ohio Railroad Company, *January* 24, 1831.

In accordance with thy request, I submit the following observations in regard to the comparative merits of canals and railways, so far as relates to their expense, facilities of construction, and benefits to the State of Maryland, in point of revenue, as well as of general advantage to the citizens.

1. *First—Comparative expense.* As a canal and a railroad cannot both be constructed between any two points on the same identical route, therefore, the evidence, by which we are to judge of their comparative expense on a given line, must consequently be that of an estimate for each, or by an approximate conclusion drawn from analogy.

I know of but one route, on which careful estimates have been made at the same time both for a canal and for a railroad. The route here alluded to, is along the Potomac river, from the Point of Rocks to Harper's Ferry, or at least so much of that route as was included in the narrow passes.

These estimates were made by N. S. Roberts and myself, as commissioners appointed by the Chancellor of Maryland to examine and survey the ground with a view to the location of the Chesapeake and Ohio canal and the Baltimore and Ohio railroad along that line. In the first place, a route was run for the canal, and an estimate made for it, without any regard to the railroad. In the next place, a route was run and estimated for the graduation and masonry of the railroad, with a view to three sets of tracks through the same narrow passes, without any regard to the canal.

From these estimates, therefore, adding to the estimates for the railroad, an average price for the laying of three tracks of railway on the graduated surface so to be prepared, we arrive at results which will give the comparative probable expense of both the canal and railroad.

The canal was assumed to be of such dimensions, that, with a depth of water of 6 feet, its cross section should contain an area of 306 square feet. The breadth of the graduation for the railroad was to be 30 feet.

Estimates for the Canal.

Lower Point of Rocks, length	3,023	feet, cost - - -	$45,766
Upper Point of Rocks, length	2,133	do - - - -	23,123
Miller's Narrows	3,052	do - - - -	30,028
Harper's Ferry Narrows,	1,126	do - - - -	28,102
Total, - - -	9,334		$127,019
Add 10 per cent. for superintendence, &c. - - - -			12,702
Amounting to - - - - - - - -			$139,721

Equal to $79,036 per mile.

Estimates for the Railroad.

Lower Point of Rocks, length	3,427	feet, cost - - -	$12,472
Upper Point of Rocks,	3,107	do - - - -	9,746
Miller's Narrows,	3,500	do - - - -	16,879
Harper's Ferry Narrows,	1,100	do - - - -	5,556
Total, - -	11,134		$44,654
Add 10 per cent. for superintendence, &c. - - - -			4,466
Also for three sets of tracks on a length of 11,134 feet, at $5,000 per mile per track, including superintendence, &c. - -			31,631
Amounting to - - - - - - - - -			$80,751

Equal to $38,294 per mile—with but a double set of tracks, the cost of the railroad, when completed, would be $33,294 per mile.

In relation to the foregoing estimates, the following remarks may be made:

1. The estimate for laying the rail track is assumed equal to the actual cost of that on the Baltimore and Ohio railroad, which has been laid with the use of wooden string pieces and stone blocks. According to the experience which we have already had, the substitution of wood sleepers for the stone blocks would result in a cost of $4,000 per mile, and the use of stone sills in lieu of either, would result in about 6,000 to 6,500 dollars per mile, as the cost of a single track, as stated in the 4th annual report of the company.

2. The estimates for the canal above stated, do not include any lockage, though there will be about forty feet of fall to provide for by locks between the Point of Rocks and Harper's Ferry. Nor is the cost estimated for lining the interior banks of the canal with stone, a precaution, without which such a work cannot be considered as finished. This conclusion results from experience had on the New York Erie canal.

The amount of this latter item would perhaps be about $ 5,000 per mile, to which must also be further added the proportional expense per mile for the requisite lockage.

3. On the whole, therefore, whether we take the estimates as already stated, or with such additions as will make them of the most permanent character, still the ratio of the probable expense of their construction will, on the ground here estimated, be about as two for the canal to one for the railroad.

4. I have not seen the last estimates for the canal on the intermediate grounds, and, therefore, cannot institute so strict a comparison with regard to them. My opinion is, that, in the most favorable ground along the river bottom lands, the expense of the canal would exceed that of the railroad from 25 to 60 per cent.

In relation to other routes. Until we have definitive calculations for a greater variety of instances in this country, than we are yet able to lay before the public in relation to this question, we can only offer our opinions upon the limited data within our reach.

In the report of the United States' Board of Internal Improvements, the cost of constructing the Chesapeake and Ohio canal from Georgetown to Cumberland, was estimated at about $ 8,000,000. It is true, other estimates have since been made reducing the amount perhaps to about $ 5,000,000. But it is understood, that, so far as the construction of that work has been prosecuted, the latter estimate has been found to be wholly inadequate, and I am of the opinion that, unless the dimensions shall be contracted, or the work be made less permanent in its character, the estimate first mentioned will not be far from the amount which that work will have actually cost, should it be completed to Cumberland.

5. It is confidently believed, that the cost of the railroad to Cumberland, inclusive of the extraordinary expense of that portion of it between Baltimore and Ellicott's mills, will not exceed $5,000,000.

The estimate made by the same board for the entire canal from Georgetown to Pittsburg, amounted to about $22,000,000. It is conceived that the cost of the railroad would not be one half of this amount, and it might not exceed one third of it.

The stupendous reservoirs and tunnel, and the numerous locks which have been considered necessary in crossing the mountains on the middle division of the canal, would be dispensed with in case of a railroad, and the

comparatively insignificant expense of inclined planes, and stationary steam power, substituted.

It is believed that the expense of constructing a canal from Baltimore to the Point of Rocks would be double what the railroad between the same points will cost.

The estimate reported by Dr. Howard, for a canal from Georgetown, D. C., to Baltimore, the length being 44¾ miles, amounted to about $2,800,000. It is not doubted but that the half of this sum would be more than ample for a railroad.*

Upon the whole, I infer, that, over rough and difficult grounds, yet such as have been pronounced practicable for a canal, the cost of a canal would be about from 50 to 100 per cent. more than that of a railroad. The former to be as spacious as such works may be expected to be made on such ground, and the latter to have a double set of tracks; and that, on the most favorable grounds which the country affords for such works, the ratio of expense may be expected to vary, from an equality to 50 per cent. in favor of railroads.

Second—Facilities for Construction. The answer to this part of the inquiry may be considered as almost included in the preceding one.

It may, however, be added, that, by reason of the supply of water necessary for canals, their number, extent, and locality, will necessarily be much more limited than railways. It may also be recollected that the minimum discharges of running streams becomes less as the country advances in agricultural and manufacturing improvements.

Railroads can be constructed, advantageously, over a considerable variety of inclination and character of surface, impracticable for canals, and their branches can be made to penetrate the glens and defiles of the mountains, where lockage would be very great, and the supply of water for canals totally insufficient, but where extensive iron and other manufacturing establishments may be located.

Third—Benefits to the State, and advantages to the citizens. The benefits and advantages, both to the State and to the citizens composing it, it is conceived, will be greater from the railroad than from the canal system.

The following observations are offered in support of this opinion:

The capital invested in a given line of railroads and canals will, in no case, be greater in the first, and will often be only half of what the latter would require, whilst the speed on the former may be four times as great as on the latter. The resistance from friction is equal through equal spaces,

* Recently, an estimate, based upon experimental surveys, (appended, marked No. 8,) has been made by me, of the probable cost of constructing a railroad upon 29 miles of this route, to wit: between the Baltimore and Ohio railroad and the northeastern boundary line of the city of Washington, amounting to $1,555,529, including contingencies and superintendence; and it is probable if the route had been extended to the basin at Baltimore, on the route surveyed for the canal, and to Georgetown, on the apparently favorable ground through Washington, so as to embrace the extreme points estimated for the canal, that the estimate for the railroad on the entire route from Baltimore to Georgetown, would have been about $2,000,000.

This estimate, however, is based upon a plan for a railroad of the first class, with a double railway of such strength, and with grades and curvatures so reduced, as to allow of the employment of the heavier locomotive engines, with the highest velocities that may be desired or admissible; and is, therefore, much higher than was contemplated in the comparison abovementioned, or than would be sufficient for a railway that would be equally effective with a canal. With less latitude than has been taken upon the roailroad between Baltimore and the Point of Rocks, as respects grade and curvature, there can be no doubt that a railroad could be constructed from Baltimore to Georgetown for one-half the estimate for the canal.

J. KNIGHT.

March 5, 1832.

whatever may be the velocity. The resistance of fluids, occasioned from a body passing through them, is rather more than in proportion to the squares of the velocities of the bodies in motion, whether it be a boat or a car; and as the density of water is to that of the air as 800 is to 1, therefore the resistance from water will be 800 times greater than the resistance from the atmosphere with an equal velocity. It is not likely, therefore, that velocities on railroads will often be as high as to require a calculation for atmospheric resistance; whilst the law by which the resistance of fluids increases, causes that resistance, in a medium so dense as water, soon to be in equilibrio with any impelling power which can be employed.

The force of the wind and of steam has been the most successful in propelling vessels upon water; but the maximum velocity, under the most favorable circumstances, (not in canals, but in seas, bays, and large rivers,) is not known to have exceeded about 13 miles per hour, whilst, on a railway, in the present yet almost infant state of that kind of improvement, more than four times that velocity is known to have been obtained.

The inference, therefore, is, especially if canals are included, that locomotion upon land by means of railroads will take place with quadruple the velocity that can possibly be attained upon water. I say *possibly*, for if any one should say that he imagines improvements will yet be made in the conveyance upon water, I answer that the probability is much greater that further improvements will yet be made in the conveyance upon land. The law of resistance is decisive of this matter, and, being a law of nature, it must always continue to operate.

Seeing, therefore, that the capital invested will be less, and that the celerity and ease of movement will be vastly greater on a railway than on a canal, and supposing, which will not be doubted when the velocity is considered, that the capacity of railways will be ample for all the wants of trade and intercourse, what can prevent the advantages of a railway being as great, nay greater, to the State and to the community, than those to result from a canal?

If it be said that goods can be conveyed cheaper on a canal, it may be remarked that the abundance of fuel in this country will always give to steam a preference as the cheapest moving power, and that this agent will secure to railways their full effect, and cannot fail to place them pre-eminent above all other modes of inland communication.

A locomotive engine and its train, conveying thirty tons of goods 120 miles in a day, would cause a daily expense of about ten dollars. This would be 3,600 tons conveyed one mile for 100 cents, that is, at the rate of 278, or a little over one quarter of a cent per ton per mile. The operation of the locomotive at Charleston, S. C. will justify this conclusion, without reference to what has been demonstrated in England.

The cost of transporting coal on the Hudson and Delaware canal, during the last season, was $1 50 per ton, exclusive of any charge for toll—the length of this canal is 108 miles. The engineers stated, however, that the company expected to reduce the charge to one dollar and twenty-five cents, which would be at the rate of $1\frac{1}{6}$ cents per ton per mile. This canal has considerable lockage, but not more than an average quantity. The larger dimensions, however, of the Lehigh canal and of the Chesapeake and Ohio canal, would, (if we except the mountain section of the latter, in which the quantity of lockage will be unprecedented) allow the charge for transportation to be less. But I do not perceive how it could, on any canal, be less

It would appear, therefore, that the cost of transportation will not be greater, but may, and probably will be less, or even one half, on a railway with locomotive engines, than it can be on the best canal; and the capital invested being less, the tolls may also be less.

Therefore, whether we regard the amount of revenue to be derived, or the facilities and general advantages to the citizens to result from the canal or railroad system, it will follow that railroads must have the preference. This preference will be rendered more decisive, when we reflect that a canal generally occupies the most valuable lands, and that it requires a much greater quantity of land for itself, its feeders, dams and reservoirs; that it interferes with the plans of irrigation and drainage, and deranges the hydraulic improvements connected with the manufacturing industry of a country, and, to that extent, crippling its powers of production, whether present or prospective; that it considerably interferes with the free access and intercourse to and from the lands and neighborhoods lying upon its opposite sides, and tends to prevent the location and use of roads where public or private convenience might require them across the route of the same—that, from the combined effects of floods, breaches, repairs, drought and cold, the average duration of its navigable condition, in our climate, is reduced to about one-half of the year—and that the navigation is tardy when in operation, being too slow for the transit of light goods, or for the conveyance of passengers, mails, or messengers; that the railroad requires a less width of ground, and none that may be required for feeders, dams or reservoirs, and will not so frequently occupy the best lands; it does not use or interfere with the streams and waters employed, or which may be employed for irrigation, or for any hydraulic or manufacturing purposes; but, on the other hand, it adds to the value, and thus immensely increases the resources and wealth of the country, and in turn the business and revenue upon the road consequently thereby become increased; that it interferes comparatively in a very small degree, if at all, with a free passage over it from side to side, either for the purpose of agriculture, or for other intercourse, or with public or private roads, whether existing or hereafter to be located; that breaches will be rare, and their effects to prevent the use of the way, will be so temporary, that very little inconvenience, if any, will be felt in consequence; repairs in general will not prevent a free use of the road, whilst their amount will be less for the railway than for the canal; that the movement upon the railway will not be impeded either by drought or cold, the only impediment during the winter season will be from a fall of snow, which it has been demonstrated is so easily removed as scarcely to offer any obstruction, and consequently that the railroad may be considered to be virtually passable throughout the whole year; that the rapidity of the movements upon it may be as great as the wants of trade and intercourse can demand, or prudence admit; not only for the conveyance of persons, and the public mails, but of every commodity for which conveyance could be sought; that, since necessity would cause railways to be preferred to canals in many places and situations, whatever might otherwise be our opinions of their relative value; and since transfers and transshipments add to the expense and risk, therefore, from this cause alone the ratio of advantage would work favorably to the railroad system throughout. For the car that issues from the mine, or from the manufactory, with its freight of minerals or of wares, would then have no obstacle to its travelling to the most remote depot; and at once delivering its freight into a warehouse, ship, coal yard, or other place, without any expense or delay on the intermediate shifting of the load. Tredgold gave his opinion in favor of a canal in a level district, but, at the same time, remarked that,

in nine cases out of ten, the railroad should be preferred. (See his Treatise on Railroads, 1825, ch. 1.) Our climate is more unfavorable to canals than that of England; in addition to which, it must be remarked, that from the inventions and improvements which have since been made, the railroad system has double, if not treble the efficiency that it had when Tredgold wrote. (See also Wood's Treatise on Railroads, 1825, ch. ix.)

In offering the foregoing remarks, it is by no means intended to controvert or dispute the utility of canals, but to make known, in a brief and summary manner, the *comparative* advantages of canals and railways so far as concerns our country, and to state explicitly my preference in favor of railways. Indeed it is obvious, that, of two States, the one adopting the railroad, and the other the canal system, the one which adopts the railroad would always continue to have a decided advantage, whether as regards its agriculture, its manufactures, or its commerce, in proportion to the greater celerity, economy, and certainty which the one system affords over the other—consequently, other things being equal, would become the most populous, wealthy, intelligent and powerful. And that whatever advantages may result to England from the high speed attainable on railways, the amount of the advantages to arise, from the same high speed, must be greatly enhanced in a country so extended and so governed as the United States.

Respectfully submitted.

JONATHAN KNIGHT,
Chief Engineer.

PHILIP E. THOMAS, *President, &c.*

No. 4.

Duration of Malleable Iron Rails and of Wheels.

The rate of wearing of the wheels and rails will be at least as 50 to 1, even when the traffic is very great. N. Wood's Treatise, p. 178.

The quantity of wearing of wrought iron tire, of locomotive engine wheels, is one-eighth of an inch per annum, (see same treatise, p. 179) equal to one-fourth of an inch in two years, which will, therefore, be about the limit of duration of the tire of these wheels.

The wheels of the common cars will be subjected to about half the weight, and be of three-fourths the diameter of the locomotive wheels, and will, therefore, last $2\times2\times\frac{3}{4}=3$ years use when the tire is malleable iron. Cast iron would wear only one-fifth part as long, (see same treatise, p. 179) but when cast in chills, the wheels will wear many years, say from 5 to 10 years, according to the degree of hardening communicated. (See same treatise, p. 69.)

Now, supposing one-fourth of an inch of wear to be admissible for the rails, and that the quantity of traffic is great, and such that the ratio of the wearing of the wheels to that of the rails is 50 to 1, then, if the malleable tire of the wheels should only last two years, the rails will last 100 years. But, although atmospheric action is scarcely perceptible in its action to deteriorate the rails of a railway in use, (see N. Wood's Treatise, p. 48,) yet they cannot be supposed to be altogether exempt from such action. We will, therefore, assume that the deterioration from this cause will equal that from the action of the wheels, and the probable duration of the rails will be 50 years.

An experiment with regard to this subject is reported to have been made upon the Stockton and Darlington railway, (see N. Wood's Treatise, p. 472) showing the loss of weight of a malleable iron rail fifteen feet long, weighing 136½ lbs., to have been half a pound in one year. If, therefore, as is probable, this rail would not be unfit for use until it had lost one-fourth of its original weight, or 34 lbs., its duration, in that case, would be 68 years.

After the rail shall become unfit for use, there will remain three-fourths of the original weight to be sold as old iron, and would probably be worth one-third of the prime cost.

In the absence of further experience, therefore, the assumption of 50 years, as the probable duration of the rails, would not appear to be too favorable.

No. 5.

Repairs of double Railway, length one mile; construction, wood strings, and sleepers.

The perishable materials will consist of—

1. Iron rails, each 15 feet long, 2¼ inches wide, and ⅝th inches thick, 44 tons, at $50 per ton, =$2,200, to which add, for turnouts, &c., 5 per cent., making $2,310, and to be renewed in 50 years.
2. Iron plates under the joinings of the rails, and spikes to fasten down the rails, $350, plus 10 per cent. for turnouts and waste, amounting to $385; to be renewed in 12 years.
3. Scantling 6 inches square for string pieces, 63,360 feet, board measure, plus 10 per cent. for turnouts, waste, and for keys=69,696 feet, at $20 per M.=$1,394; to be renewed in 12 years.
4. Sleepers of wood, in number 2,640, plus 160 for waste and for turnouts =2,800, at 20 cents=$560; and to be renewed in 12 years.

Now, the annual charge of these respective items will be measured by the annuities, which, being yearly invested ,together with the accruing interests, will amount to the several sums required at the time the repairs are to be made. To insure the investments, the interest has been calculated at five per cent. per annum.

The annual charge for these four items and for labor, will, therefore, be as follow:

Materials.	1. Annuity amounting to $2,310 in 50 years,		- -	$11 04
	2. Do do $385 in 12 years,		- -	24 18
	3. Do do $1,394 in 12 years,		- -	87 57
	4. Do do $560 in 12 years,		- -	35 18
Labor. 5.	Transportation and distribution of materials, - - -	$500		
	Re-laying the railway, at $5 per rod,	1,600		
	Superintendence and contingencies,	400		
		2,500 in 12 years,	-	157 04
	Annual charge for renewing the railway,		-	$315 01
	6. Opening ditches and making other miner repairs, per annum,			185 00
			Total,	$500 01

No. 6.

Abstract of commodities, and number of passengers transported on the Baltimore and Ohio Railroad, from the 1st January to the 25th February, 1832, inclusive, viz.

Westward.

Lumber,	Tons,	128	0	0	0
Coal,		229	0	0	0
Iron,		107	13	0	0
Grain,		68	11	0	0
Groceries, plaster, bricks, &c. &c.,		561	12	0	0
	Tons,	1,094	16	0	0

Eastward.

Flour, 33,800 bbls.	Tons, 3,259	5	2	0					
Whiskey, 223 "	33	15	0	0					
Firewood,	2,481	0	0	0					
Timber, (for mechanical purposes)	18	1	0	0					
Tanners' bark,	9	0	0	0					
Iron,	138	16	0	0					
Nails	29	18	0	0					
Granite,	647	16	0	0					
Wheat,	14	7	0	0					
Rye,	41	11	0	0					
Corn,	34	5	0	0					
Shorts and shipstuff,	54	18	0	0					
Pork,	5	15	0	0					
Tobacco,	1	14	0	0					
Furniture, leather, lime, glue, &c.,	31	15	0	0					
					6,801	16	2	0	
Total tonnage,					7,896	12	2	0	

Passengers.

Westward,	2,352	4,760
Eastward,	2,408	

Office of Transportation
Balt. and Ohio Railroad.

W. WOODVILLE,
Aud'r and Sup't B. & O. Railroad.

No. 7.

Observations upon the cost of the Liverpool and Manchester Railway.

Brick making accounts.—The greater part of these bricks are fast using in the building of the Manchester warehouses, offices, &c. and some in completing the bridges at each end of the line.

Bridges.—The foregoing description of the several bridges, in a tabular form, I have thought would not be uninteresting, as affording a popular view of the kind of structures that may be expected to occur in similar undertakings. It will be seen that several of the bridges are unfinished, though fast approaching their completion. For this purpose, a fund is reserved, as per the estimate below.

Chat Moss.—Under this head is comprised the earth work from Bury-lane bridge to Legas occupation bridge, on the east border of the Moss, a distance of 4¾ miles. The embankments in this space consist of 277,000 cubic yards of moss earth, in the formation of which about 677,000 cubic yards of raw moss have been used; the difference in measurement being occasioned by the squeezing out of the superabundant water, and consequent consolidation of the moss. The expenditure on this district has been less than the average expenditure of the rest of the line.

Cuttings and embankments.—Under this head, is comprised the earth work on the whole line, exclusive of the Chat Moss district. The cuttings somewhat exceed the embankments, the surplus is principally deposited along the border of the great Kenyon cutting. The excavations consist of about 722,000 cubic yards of rock and slate, (including some side cuttings at Eccles to expedite and improve the consistency of the Barton embankment) and about 2,006,000 cubic yards of marle, earth, and sand. This aggregate mass has been removed to various distances, from a few furlongs to between three and four miles, and no inconsiderable portion of it has been hoisted up by machinery, from a depth af 30 to 50 feet, to be deposited on the surface above, either to remain in permanent spoil banks, as at Kenyon, or to be afterwards carried to the next embankment, as at the deep cutting through Olive mount; the process in this latter case being rendered expedient from considerations of increased expedition. Where land for the deposite of spoil banks has been purchased, the cost of the land forms part of the expenditure under this head, and a good deal of substantial and lofty walling in the deep cuttings is also included. The unavoidable expense of pumping out the water from the several cuttings on the line, during a wet season, was adverted to in the text.

Formation of the permanent road.—This consists of what is termed ballasting the road, that is, depositing a layer of broken rock and sand about two feet thick, viz. one foot *below* the blocks, and one foot distributed *between* them, serving to keep them firm in their places. Spiking down the iron chairs to the blocks or sleepers, fastening the rails to the chairs with iron keys, and adjusting the railway to the exact width, and curve, and level, come under this head of expenditure.

Iron rail account.—This expenditure comprises the following items: Rails for a double way from Liverpool to Manchester, with occasional lines of communication and additional side lines at the different depôts, being about 35 miles of double way, = 3,847 tons, at prices averaging something

less than £12 10*s*. per ton - - - - - -	£48,000 0 0
Cast iron chairs, 1,428 tons, at an average of £10 10*s*. -	15,000 0 0
Cost of spikes and keys to fasten the chairs to the blocks and the rails to the chair - - - - - -	3,830 0 0
Cost of oak plugs for the blocks - - - -	615 0 0
Sundry freights, cartages, &c. &c. - - - -	467 0 2
	£67,912 0 2

Land.—This is a heavy item of expenditure. The price of land in the vicinity of large towns is usually high, and the outlay was farther enhanced by numerous claims for compensation, owing to the prejudice which, a few years since, existed against railways, and especially against what now appears their peculiar recommendation—the locomotive engine. A great change has taken place in this respect. At the close of 1828, the charge under this head was nearly £102,000, but a portion of this amount, being for the depôts, has been transferred to the carrying department.

Office establishment.—This comprises the salaries of treasurer and clerks, office rent, stationery, printing, &c. since October, 1824.

Stone blocks and sleepers.—Out of the 31 miles, about 18 are laid with stone blocks, and 13 with wood sleepers, oak or larch; these latter being laid principally across the embankments, and across the two districts of moss. A considerable quantity of wood sleepers have been destroyed, unavoidably, in the progress of the work.

Surveying account.—This comprises the cost of surveys, plans, &c. for the two applications to Parliament in 1825 and 1826; also, the salaries of the engineer and principal assistants, stationery, &c. from the commencement of the undertaking.

Travelling expenses.—This includes the cost of sundry journeys and deputations to London, Darlington, Newcastle, &c. since 1824; also the cost of journeys of inspection on the line of railway during the progress of the works.

Tunnel compensation account.—This consists of compensation paid to parties under whose premises the Liverpool tunnel is excavated, for damage, either real or supposed; and, farther, of loss sustained on the resale of sundry houses and lands which the company were required to purchase. There will be a credit to this account, for premises resold, to the extent of about £2,500.

Wagon account.—This expenditure is principally for wagons used in the progress of the work. There will be a credit to this account from the resale of such wagons as cannot conveniently be adapted to the future purposes of the railway, and by a transfer of the remainder to the carrying department, at their estimated value. It will be observed that the statement of expenditure is up to the 31st of May, 1830; the railway, however, will require a farther outlay to render it complete, though the locomotive engine has passed over every foot of ground from Liverpool to Salford. The slopes of the cuttings want dressing, and several of them want protecting with foot walls. The permanent roadway is not quite finished, and some portions that have been laid down require adjusting and re-leveling. The fencing, also, in portions of the line, will be incomplete for some time.

The Directors, in their report dated 25th March last, estimated the total expenditure, including warehouses, machinery, and carriages, at £820,000, which may be apportioned as follows:

Expenditure as above, in actual payments, to 31st May -	£739,165 5 0
Outstanding engagements to the same date - - -	7,500 0 0
For walling the slopes in sundry places, and completing permanent road - - - - - - -	6,750 0 0
For completing the bridges, including the Irwell, £6,000, and parapets of the Saukey viaduct £1,400, and compensation in lieu of bridges - - - - - - -	9,500 0 0
Additional engines, wagons, and machinery, part under contract for delivery - - - - - - -	17,000 0 0

Completing stations, wharves, warehouses, &c. - -	25,000 0 0
Fencing at sundry places - - - - -	3,000 0 0
Contingencies - - - - - - -	12,084 0 0
	£820,000 0 0

WASHINGTON, *March 17th*, 1832.

I now enclose an account of the increase of the trade and income of the Liverpool and Manchester railway, being a comparison of that of the two half years of 1831, and which I mentioned it was my desire to obtain and have added to the essay already sent by thee to Gen. Mercer, the chairman of the committee. It consists of an extract from No. 11 of the "American Railroad Journal;" D. K. Minor, New York, 10th March, 1832.

My request is that the enclosed paper, already described, may be added to my document No. 7, in the character of a note to it.

Very respectfully,
J. KNIGHT.

Hon. B. C. HOWARD.

Extract from No. 11 *of the "American Railroad Journal:" D. K. Minor, New York,* 10*th March,* 1832.

LIVERPOOL AND MANCHESTER RAILWAY.

It appears from the following statement, taken from the report just printed and circulated amongst the proprietors of the Liverpool and Manchester railway, that the trade and revenue are increasing rapidly:

	Tons of goods.
During the half year, ending 30th of June last, there were conveyed between Manchcester and Liverpool - -	35,865
During the half year, ending 31st December last, sent -	50,234
Increase - - - - - - -	14,369 tons.
Goods for Bolton and other parts of the road, during the half year ending the 30th June - - - - -	6,827
Goods for Bolton and other parts of road for the half year ending 31st December - - - - -	12,997
Increase - - - - - - -	6,170 tons.
Coals to Liverpool for the half year, ending 30th June -	2,889
Do do for do do 31st December	8,197
Increase - - - - - - -	5,308 tons.

Being an increase of 25,847 tons, or 50 per cent. upon the last, as compared with the preceding half year.

As respects passengers, an opinion was pretty generally entertained that, as soon as the novelty of steam conveyance had ceased, the number of passengers would fall off. The report, just circulated, shows a very different result.

Passengers entered in the company's books during the half year, ending 30th June - - - - - - -	188,726
Passengers entered in the company's books during the half year, ending 31st December last, being - - - -	256,321
Increase - - - - - -	67,595

Being upwards of 33 per cent. increase for the last six months beyond the first six months of the year, and upwards of 135 per cent. increase on the travellers, between the two towns, during the corresponding months previously to opening the railway.

As respects the revenue, this has increased, of course, very considerably.

	£.	s.	d.
The revenue from coaches for half the year, ending 30th June - - - - - - -	43,600	7	5
The revenue from coaches for the half year ending 31st December last - - - - - -	58,229	5	0
Increase - - - - - -	14,628	17	7
The revenue for merchandise for half year ending 30th June, was - - - - - -	21,875	0	1
The revenue for merchandise for last half year -	31,085	18	4
Increase - - - - - -	9,210	18	3
The revenue from coal for half year ending 30th June, was - - - - - - -	218	6	0
The revenue from coal for the last half year - -	692	10	7
Increase - - - - - -	474	4	7
Making a total increase upon the last half year, as compared with the preceding, of - - - -	24,314	0	50

No. 8.

Communication from the President of the Baltimore and Ohio Railroad Company to the Legislature of Maryland, enclosing surveys and estimates of the Railroad from Baltimore to Washington.

Office of the Baltimore and Ohio Railroad Company,
February 21, 1832.

Esteemed Friend: The Legislature of Maryland having, at the last session, passed a law authorizing the Baltimore and Ohio Railroad Company to lay out, survey, locate, and construct a railroad from some point on the

Baltimore and Ohio railroad already constructed, within eight miles of the city of Baltimore, to the line of this State, adjoining the District of Columbia, in a direct line towards the city of Washington, along the most direct and suitable route that might be reasonably and conveniently practicable, the directors of this company were desirous of ascertaining, as well the facilities which the intermediate country between the cities of Washington and Baltimore afforded for the location of a direct and efficient railroad, as also the probable cost of the construction of such a road in a manner worthy of its position, between the principal commercial city of this State and the Capitol of the United States, and as a part of the great highway between the southern and eastern States, in order that it might be ascertained whether this company could undertake to avail themselves of the authority granted by the law here referred to. As early, therefore, after the passage of this act, as their chief engineer could be spared from the important duties in which he was then engaged in relation to the location of the route for the railroad between Baltimore and the Potomac river, the board directed that officer to proceed, with all his assistants, to make the necessary examinations, surveys, and estimates, and report the results as soon as practicable. After a most careful and assiduous attention to the duties assigned to him, the engineer has completed the general preliminary surveys and estimates; and I now have the pleasure to enclose to thee a copy of his report, which I respectfully request may be laid before the House of Delegates.

By this report, it will be seen that a sum exceeding fifteen hundred thousand dollars will be necessary for the construction and completion, in a competent manner, of such a railroad as will be adequate to effect the great object contemplated; and the experience of the directors justifies them in reposing the fullest confidence in the correctness of the report in all its details and estimates.

It may be proper for me to add, for the information of the Legislature, that the sum that appears to be necessary for effecting this most desirable improvement, greatly exceeds the amount which the directors feel themselves authorized, at this time, to divert from the principal object contemplated by the company, and to effect which they were incorporated—the connexion of the principal commercial city of Maryland, by an easy, speedy, safe, and cheap mode of intercommunication with the western States—an object of the first importance to the prosperity of Maryland. At the same time, the directors cannot but consider a similar intercourse between Baltimore and the Capitol of the Union as second only in importance to this great object, and in fact as properly forming a part of it, since its early accomplishment would, in an eminent degree, contribute to secure the accomplishment of the principal work—a work which, when completed, will be amongst the most magnificent, as well as extensively useful improvements, ever accomplished by human efforts. Such a work is, therefore, peculiarly deserving of the further aid and patronage of the State, more especially as the assistance already accorded has been productive of so much benefit, and has enabled the company to afford a demonstration that has resulted in the most satisfactory assurance of its certain and triumphant accomplishment.

Permit me then, respectfully, but earnestly, to ask the favorable attention of the Legislature to this subject, so vitally important to the welfare and prosperity of the citizens of Maryland. The aid of the State will ensure the construction of a railway between Baltimore and Washington, of the capacities described in the report herewith transmitted. At an early period, a

portion of the funds necessary will be cheerfully furnished by the individual stockholders, and it is believed that the city of Baltimore will as readily furnish another part. The liberal encouragement we have already experienced from the Legislature, and the great benefit which must result to the State from the execution of the proposed work, will not permit a doubt but that the representatives of the people of Maryland will also promptly contribute to it accomplishment, and that they will not suffer the energies of this company to be paralyzed for want of patronage and support.

With the assurance of my high regard and esteem,

I am, very respectfully,

Thy friend,

P. E. THOMAS, *President*,

Baltimore and Ohio Railroad Company.

The Hon. RICHARD THOMAS,

Speaker of the House of Delegates.

REPORT.

ENGINEER'S OFFICE, BALTIMORE AND OHIO RAILROAD,

Baltimore, February 17th, 1832.

The calculations and estimates of the probable amount of expense that will be required in the construction of the contemplated railroad to connect the cities of Washington and Baltimore, having just been finished, I take the earliest occasion, in accordance with thy request, to communicate the general results.

In the first place, however, it may be proper to give a concise general description of the proposed plan and profile of the contemplated railway, and to advert to the character of the country over which the route must be conducted.

The purpose of this railway being to effect an easy and rapid communication between the national capital and the third city in the Union, as well as to form an important and permanent part of the great inland highway that must, in connection with the seat of the General Government, exist, and always be used, in a direction parallel to the coast, through Richmond, Charleston, and Savannah, to the south; and Baltimore, Philadelphia, New York, and Boston, to the north; it would appear to be a concern involving great general interests, and the benefits of which would descend to remote generations.

The railroad under consideration, therefore, will have a national character, and should be planned and constructed in a manner worthy of its highly important position and functions.

To do less than this, would be to mar a great national work, to the loss of the investment, and to the lasting detriment of our character for science and enterprise. The capabilities of the road should, therefore, be such that no other work of any conceivable description could be brought into successful competition with it.

In this is involved considerations of speed and motive power, both scientific and practical, and these again must regard the resistances to be overcome, whether arising from friction, gravity, or the passing of curves. Friction upon railways has, within a few years past, undergone great and

important reductions; and it may be that the final term to which its ratio has been approximating, is not yet attained. From a careful consideration of this important item of resistance, and assuming the average of that of the two best kinds of cars now in use, and making allowance for practical imperfections in the railway, and supposing also the wheels to be three feet in diameter, I have no doubt that the attainable rate of the friction will be such as to reduce the traction on a level to less than the 30th part of the weight moved; but as wheels of less diameter may be employed for common cars, I shall assume the practical traction at an average equal to 264th. This resistance, therefore, will be equal to the gravity down a line of railway, descending at the rate of one in 264, or 20 feet per mile; consequently the inclinations of a railway from a level should not exceed this rate.

All motive agents, mechanical as well as animal, are capable of exerting, for a short time, and, occasionally, twice the power, that their regular and constant average work or movements require when the effect produced is a maximum. This has been demonstrated by the mathematician, and has likewise been found to accord with experience. Hence, the ascending lines of a road of any description should not have a grade requiring more than double the power necessary on the level parts of the same road. The power required on the ascent of the railway, at the rate of 20 feet per mile, will be double of that required on *a level*, in addition to that which will be necessary to counteract the gravity of the motive agent. If, therefore, whilst the friction is the 264th, the ascents and descents are greater than one in 264, there will either be a loss of time, or else an unnecessary surplus of power would exist on the level parts of the railway. In either case, there will be a loss of effect when compared with the cost of transmit.

Moreover, since, with the use of locomotive steam power upon this railway, the velocity on the level parts should be as great as will comport with due safety; it follows that the velocities, upon the descending, should not be greater than upon the level parts; and, therefore, any acceleration from gravity would not be useful, and could not be employed to any valuable extent in this particular instance. Consequently, in descending, as well as in ascending, an inclination exceeding 20 feet in the mile would be disadvantageous.

Although the grade had been restricted, as already mentioned, to one in 264 as the maximum, it was still desirable that it should be less than this limit, and that as much of the road should be level as the surface of the country to be traversed would admit of, consistently with a due regard to the expense of construction.

It was evident, that the velocities to be employed upon this road would be as high as confidence and safety would permit, and that a speed of about twenty miles per hour must be attained, so as to perform the trip from city to city within *two hours.* This will probably require the use of a locomotive engine, weighing six tons, to convey a train of six cars, containing one hundred passengers in the time proposed; for, although the adhesion of the wheels of a $4\frac{1}{2}$ ton engine would be sufficient for the draught of this train upon an ascent of 20 feet per mile, yet it is doubted whether its capacity for the generation of steam would be adequate to the whole performance within the specified time.

Taking it then for granted, that a six ton engine will be employed, and that the speed will be made to average twenty miles per hour, it becomes necessary that the road should be comparatively straight, in order that the

centrifugal force, in curves, may be small, and the stability of the engine and its train upon the rails insured; and likewise, that the unnecessary *wear tear* should be prevented, and, at the same time, the power economized.

It was consequently concluded to make the curvatures so slight as to admit of the use of locomotive engine wheels of a diameter of four or five feet, and so that just such engines in all respects as are now used on the Liverpool and Manchester railway, could be run upon this road.

The minimum radius of curvature was assumed at 1400 feet. It is now known, however, that the line may be so laid that the radius of curvature shall, in no place, be less than 2000, and, in very few places, less than 3000 feet, whilst the ascents and descents shall not, in any part, exceed twenty feet per mile.

The greater part of the experimental lines already run, with a view to this railway, have been traced, with a view to the limits of grade and curvature already mentioned, and the estimates are made for a line of this character.

A line more nearly approaching to that of a perfectly straight and horizontal line would have been preferred, but the character of the country does not admit of it within any practicable limits of expense in the construction, nor would the gain in the motive power be a sufficient return for the capital which must be added to make any material reduction in the altitudes of the summits to be passed, beyond such as are contemplated in the estimates.

The ridges crossed between the Baltimore and Ohio railroad and Bladensburg, are three in number; the first divides the slopes of the Patapsco and Patuxent rivers; the second the two branches of the Patuxent; and the third the Patuxent and the Northeastern Branch of Potomac. The altitudes of these ridges, at the comparatively low points at which they are crossed, vary from 200 to 215 feet above the level of mid tide at Baltimore, and cuts, from 40 to 50 feet in depth will be required, at the same time that the Patapsco and each of the Patuxents must be crossed at altitudes above them of from 40 to 50 feet respectively. It will, however, depend upon the result of surveys yet to be made, whether the route may be laid across the second and third ridges just mentioned, at points less elevated; but it is not expected, that this would materially reduce the amount of the estimate, as the route would be lengthened by the change; yet the question will involve considerations connected with the moving power to an extent that should not be disregarded in a route of such magnitude. The Patapsco may be crossed either at an altitude of 50 feet, or of 66 feet above tide, according as the one or the other of the two places proposed shall be ultimately selected for this purpose.

From the Patapsco to the first ridge, in a distance of about six miles, the route passes up the valley of Deep Run. In consequence of the uniformity of the extreme grade necessary to be adopted in order to gain the summit at an altitude of 165 feet above tide, the line is here thrown upon very rough, uneven ground, encountering a succession of spurs from the ridges, and deep indentations at the lateral small streams which have to be crossed; thus making the graduation of this part of the line very expensive. Thence to the head drains of the Northeastern Branch, a distance of about ten miles, the route continues to be equally expensive, in consequence of the cuts through the three ridges before mentioned, and the embankments across the valleys of the two Patuxents. The tributary of the Northeastern Branch having been gained, the route for about eight miles in its descent down the valley of that stream, to Bladensburg, is remarkably favorable. At Bladensburg, the valley of the Northwestern Branch must be crossed with a long em-

bankment, from 30 to 35 feet in height, and thence to the line of the plat of the city of Washington, a distance of about four miles, the route is rough, and will require much heavy excavation.

From the line of the city of Washington, the railway can be conducted to the General Post Office in the further distance of about two miles, upon such route, and to such other point as shall be agreed upon. The uncertainty, however, of the future position of this part of the line renders it impossible at this time to extend the estimates to any point within the city boundary.

The materials to be excavated will consist of sand, gravel, and clay; the latter will, probably, in places, be found to be of a hard texture, and such as has been encountered on the first seven miles of the Baltimore and Ohio railroad. This will probably be the case along Deep Run, and also between Bladensburg and Washington. With these exceptions, a greater portion of sand and gravel may be found to obtain. Very little rock will be found in the whole extent of the route.

The estimate for the graduation has been carefully made up from the details of the several excavations and embankments, with a view as well to the supposed degree of tenacity of the material to be excavated, as to the distance it must be transported in executing the work, and the width of the road bed to accommodate a double railway, that is two tracks, and the ditches necessary for drainage.

The masonry has been estimated on the plan of stone culverts and substantial stone arched bridges, without ornament or any unnecessary dressing. The stone will be found on the Patapsco, the two Patuxents, the Northwestern Branch, and on the Potomac generally, within a distance, probably, of 5 or 6 miles of the site of the works to be constructed. In estimating the masonry, due regard has been paid to the probable expense of securing the foundations, the quality of the work, the quantity of the materials, the distance of transportation, and the proportions of the parts.

In estimating the cost of the railway, regard has been had to the action it will have to sustain, the quantity and quality of the materials to be used in the construction, to the necessary labor to be expended, and to contingencies and superintendence.

It is confidently believed that the great *ends* to be expected from the establishment and use of this important avenue of communication, will be attained, should the plan and profile, as already described, be adopted, and a railway suited to the action of locomotive engines, weighing six tons, be constructed.

With a view to the action of such engines in high volocities, it is proposed to lay down rails of a description different from those on the Baltimore and Ohio railroad. The absence of stone suitable for sills thoughout this entire line, renders it impracticable, in the first instance, to use that material in the construction; and it may be likewise remarked, that even were this material sufficiently abundant, it would be some years before the embankments would be sufficiently settled to receive a structure of this kind.

These circumstances compel the use of wood instead of stone to support the iron rails, and it is proposed to place the sleepers or tie-pieces three feet apart instead of four feet as heretofore, and to use string pieces of wood underneath the sleepers in addition to those laid upon them, in order to strengthen the track, and to prevent unequal and partial settling. These under timbers may be various in their dimensions, and such as are to be procured with

most convenience. The upper string pieces, however, which rest upon the sleepers, and on which the iron rails will be placed, are proposed to be six inches square, of southern pine scantling, and of the best quality that can be obtained. The iron rails will have a continuous flat base, in width 3½ inches, resting upon the wood; each rail will be about 15 feet in length, and about 2 inches in height, so as to permit the flanges of the wheels to play above the base plate. These rails will be rolled of such form as to economize the quantity of iron to the greatest extent consistent with utility. The rail will weigh about 32 pound per running yard, and it will require 50 tons for each mile of single track.

With regard to the policy of estimating for two sets of tracks instead of one only, it may be proper to observe, that, although there is little doubt that the capacity of a single track, with the proposed velocities, would be sufficient to effect the whole of the transit that would be required upon the proposed railway for some years to come, yet when it is considered that repairs will be needed, and that, for these purposes, materials must be conveyed for long distances on the line, and that considerable quantities of earth must occasionally be removed from the ditches in the long and deep cuttings, and transported in railway cars to supply defects in embankments, or to some other place of deposite, and when it is also considered that two tracks would allow the business of the road to be performed in the day time, whilst the number of trains, and their hours of departure and arrival could be increased as circumstances should require, the belief is entertained that it will be advantageous to have two sets of tracks.

The difficulties to be overcome having been adverted to, and the plan of the work described, it will be proper, next in order, to give the results of the estimates.

The mason work will consist of 6,357 perches of culvert masonry, estimated to cost $24,010, being an average of $3 77¾ per perch of 25 cubic feet, together with 32,380 perches of bridge masonary, in which arches are to be made. The cost of this item is estimated at $215,135, or at the rate of $6 64½ per perch: amounting, together, to 38,737 perches of masonry, and costing $239,145, being an average of $6 17⅓ per perch. This charge is considerably enhanced in consequence of the estimated expense of securing the foundations for the works.

The total mass of earth and other material to be excavated, removed and supplied, to effect the entire graduation, is calculated to be two millions four hundred and sixty thousand seven hundred and sixty-one cubic yards, estimated to cost the sum of $779,518 15, being an average of 32.39 cents per cubic yard.

The length of the route included in the estimate is 29 miles.

Summary.

Graduation, 2,406,761 cubic yards, at $3,239, -	$779,518 15
Masonry, 38,737 perches, at $6 17⅓, - -	239,145 00
Amounting to - -	1,018,663 15
Add 10 per cent. for contingencies and superintendence,	101,866 32
	1,120,529 47
Railway double track 29 miles, at $15,000 per mile,	435,000 00
Total amount - -	$1,555,529 47

The details of the estimate from which the foregoing results have been obtained, are in this office, and statements of them will be reported if necessary. Maps and profiles are likewise nearly completed, representing the several routes surveyed.

The final location of the route of the railway can be commenced as soon as the weather will permit.

In making the estimates, I have been assisted, with regard to the masonry, by Robert Wilson, assistant superintendent of masonry; and so far as relates to the structure of a track of railway, by James P. Stabler, superintendent of construction of the Baltimore and Ohio railroad.

In the surveys, drawings, and calculations, I have been aided by Henry J. Ranney, Benj. H. Latrobe, and the other young gentlemen named in my last annual report.

All which is respectfully submitted.

J. KNIGHT, *Chief Engineer.*

Extract from the report of the Committee on Railroads of the New York Legislature on so much of the Governor's message as relates to that subject.

Mr. Stilwell, from the Committee on Railroads, to which was referred so much of the Governor's message as relates to the construction of railroads, and the incorporation of companies for that object, submitted the following report:

The important and responsible duties assigned to your committee have been duly appreciated, and the zeal which animates to the discharge of trusts however arduous, has impelled them forward under the various difficulties which they have had to encounter. The brief space which is allowed in the daily routine of legislative duties, scarcely leaves sufficient leisure to prepare for the investigation of the public any document which may be a subject of material interest. Your committee have lost no time, however, and have spared no pains to meet the expectations of all.

Perhaps no subject, since the foundation of this Government, has engrossed the public mind to so great an extent as the one under consideration; and as a necessary consequence, the halls of the Legislature are crowded with applicants seeking permission, from the sovereignty of the State, for liberty to reap the rich and honorable reward which their imaginations may picture as the consequence of success.

Excitements of the character which at present pervade the public mind, must arise from one of two causes. Either from a settled conviction that the object to be obtained will be a source of profit to the stockholders and of the public, or from a desire to throw before the public the means by which speculation may be promoted, and the few enrich themselves at the expense of the many: to promote the former is the province of the Legislature—to discourage the latter is their duty.

Entertaining these views, the committee have felt it their duty to examine more minutely into the subject referred to them, than would seem, on first reflection, to be required; and, in the range of inquiry they have proposed, they will proceed to examine into the practicability of the system which has called forth such general and enthusiastic expressions of opinion.

There is scarcely any more important means of advancing the prosperity of a country than by a good system of internal communication. The great-

er the facility of travelling from place to place, the more active will be the social and commercial intercourse; and, the more ready the transmission of all the fruits of the earth, and all the products of manufactures, the more rapid the extension of improvements and inventions, and the more complete will be the dissemination of knowledge. Time is money in all operations requiring labor, and therefore a saving of time will be a saving of money. Every country embraces more or less of territory which would be highly valuable but for its seclusion and distance from the more populous districts;—by easy and quick modes of conveyance, these disadvantages are overcome, and the most may be made of the capabilities of a country.

The various means which human ingenuity has devised for effecting an extensive intercourse in the present state of knowledge, consist of roads, railways, and canals.

The enterprise of our citizens was, at an early, period turned to the first, and, if we may credit accounts on this subject, scarcely less anxiety was felt at that time to obtain grants from the Legislature for the construction of turnpike roads, than is now evinced to obtain railroad privileges. These early enterprises did not yield much pecuniary profit to the stockholders; nevertheless they were of incalculable good to this young but growing country. The facilities of intercourse were promoted, and the general interests of the community were advanced. Next in succession came the desire for canals. The State having yielded her assent, the construction of the Erie canal presented at once a new and interesting view of the benefits of this mode of internal communication—the public mind again became engaged in works of internal improvement, and, to what extent this feeling prevailed, may be learned from the following extract taken from the message of the Governor in the year 1827. "The canals, which now principally occupy the public attention, embrace a navigable union of the principal bays on Long Island—of the Delaware and Hudson rivers—of the Erie canal, with the east and west branches of the Susquehannah—with the Alleghany river —with Lake Ontario, by Great Sodus bay—with Black and St. Lawrence rivers, and between the latter river and lake Champlain; and even a canal from Lake Erie to the Hudson river, by an entire new route, has been suggested as practicable and expedient, and urged with great earnestness and energy." At the time this message was communicated to the Legislature, only one charter for a railroad had been granted, and of so little importance was this new mode of conveyance considered, that the Governor did not even allude to the subject, and individuals could not be found possessed of means and faith sufficient to fill the stock and undertake the enterprise. The public have thus been led on from one useful and patriotic improvement to another, constantly developing new resources, and holding out for example and emulation some of the most bold, useful, and successful enterprises, that any country in any age has ever witnessed. From the knowledge we possess of the rapid advance of our fellow citizens in this knowledge of their wants and resources, and the most efficient manner of developing them, it will not be necessary for us to more than hint at the difference between the two last mentioned improvements.

The object of any mode of communication is to facilitate the transportation of heavy bodies from one section of the country to another. It consequently must be so ordered as to overcome those obstacles or irregularities, in the surface, which nature has placed between the points to be connected.

The principle on which the railway operates in effecting this object, dif-

fers essentially from that of a canal. In the latter, the body to be moved is sustained by the greater gravity of the fluid on which it is placed, and the yielding nature of the particles which compose that fluid permits the body to move along the surface under a moderate application of force. This fluid is thrown into an artificial channel, constructed for the purpose, and ranges through the whole extent of country to be united. In the former, the weight to be transported is contained on rollers or wheels, and is made to move under the application of a comparatively moderate force, along the hard and even surface of planes, either level or partially inclined.

Upon a canal, with an extremely moderate motion, the difference between the weight moved and the propelling power is exceedingly great. This difference diminishes rapidly with an increase of velocity. The resistance encountered lies in the gravity of the water, a nature which it is not possible to alter, or in anywise to control.

Upon a level railway, the resistance to be encountered consists principally of the friction at the axles of the carriages, and the flexure of the rails, and is not materially affected by a change in the velocity.

Canals are confined to comparatively low districts, on account of the necessity of an adequate supply of water, and of the expense and delay of locks and lockage. Railways may be made to traverse regions however elevated, and the ascents and descents are not only not limited, but they are overcome in a comparatively short space of time, owing to the great superiority which inclined planes possess over locks.

Canals experience the change of the seasons most sensibly; the drought, the floods, and the frost, are serious and insurmountable impediments to their construction, and whether they be constructed in the frigid, temperate, or torrid zone, the effect of such changes cannot be avoided.

Railways are said not to be affected by either; and certainly the two first cannot operate upon them. The last has been a subject of speculation among the inexperienced, and, as the construction of railways in this country is of so recent date, perhaps we may not be enabled to rely with implicit confidence on such experiments as have been made.

The Baltimore and Ohio Railroad Company, however, furnishes some evidence on this point, and would seem to put this question at rest. Under date of the 31st of December last, the Baltimore American says: "while all the communications by river and canal throughout the country are suspended on account of the ice, our great railroad continues in active and steady operation, *without the least interruption or hindrance from frost, snow*, or any other obstacle. The passenger carriages, generally full both ways, have traversed the line of sixty miles between Baltimore and Frederick, *daily, since the opening of the road.*" This fact tends to prove that railroads may be used at all seasons of the year. The difference, however, between the climate of Maryland and New York, may be assigned as a reason for still urging this latter objection, and is certainly worthy of consideration.

In consequence of the almost exclusive use of steam power on railways, this question, on some routes, may be one of serious import, and would require close and satisfactory investigation, before entering upon the construction of any road, the utility and profit of which depend solely on the business of the winter: on any other route it cannot be a matter of so much moment, for if it would be a good reason to deter from the construction of railroads, it might be urged with much more force against canals. Many

propositions have been made to obviate this difficulty, but as the question does not seem to be entirely settled by experience, the committee are not prepared to point out any remedy or express any opinion. They may, however, safely anticipate, that all obstacles which are not insurmountable, will be overcome by the ingenuity and enterprise of our citizens. Many difficulties have already been overcome, and, as the spirit of improvement has, by recent discovery, received a new impetus, we are warranted in the most sanguine anticipations of entire success.

The first mention of railroads in England, is made in the year 1600; they were then made for crossing marshes, where materials could not be procured for constructing a solid road; subsequently they were used for transporting heavy bodies for short distances, and, at Newcastle-upon-Tyne, for conveying coal from the mines to the furnace. In Russia they have been in use for many years. The first description of them we find in the year 1676: they are thus described:—"The manner of the carriage is by laying rails of timber from the colliery to the river, exactly straight and parallel; and bulky carts are made with four rollers, fitting those rails, whereby the carriage is so easy that one horse will draw four or five chaldrons of coals, and is an immense benefit to the coal merchant." Iron tracks have since been substituted and used with great advantage, when an efficient and economical mode of transportation was found necessary.

It is only within a few years, however, that any considerable attempts have been made to establish railways for general purposes. The entire success of these undertakings has fully proved the superiority of this kind of conveyance, and the English are now engaged in such an extension of their system of railroads, as promises results of the most important character.

The aggregate length of railroads in Great Britain, including those now constructing, is estimated at near 3,000 miles.

The introduction of the locomotive engine, as a moving power on railways, and the extraordinary increase of speed as well as power which has been thereby attained, promise to work a revolution in human affairs as great as has been accomplished by the application of steam to the purposes of navigation.

"Twenty years ago, we believe, the mails did not travel faster than about seven miles an hour. From seven miles it was raised to eight, and every one cried what an improvement! From eight it was raised to nine, and this was hailed as nothing less than 'prodigious!'" Attempts are making to force it up to ten miles an hour, but to any thing beyond this, to a certainty, horse power fails us. How then shall we find terms adequate to express the value of a discovery that carries us at once from ten to twenty or thirty miles an hour?

The experiments which have been made in England go far to prove that we have not yet arrived at the point where improvement in speed must cease. The present average of speed upon the Liverpool and Manchester railway is sixteen miles per hour. The maximum velocity, unloaded, is thirty-two miles per hour. With a load of thirteen tons, including many passengers, Mr. Stevenson's engine, the Rocket, travelled at the rate of fifteen miles an hour; and the engine of Braithwaite and Erickson, of Londan, moved at the astonishing speed of twenty-eight miles an hour. "It seemed indeed," said a spectator, "to fly, presenting one of the most sublimespectacles of human ingenuity and human daring the world ever beheld.

It actually made one giddy to look at it, and filled thousands with lively fear for the safety of individuals who were on it, and who seemed not to run along the earth, but to fly, as it were, on the wings of the wind. When the vehicle," he continues, "nicely poised on springs, and covered in to exclude the external current of air created by its motion, you might imagine you were in a state of perfect rest, while you are flying along the surface with the speed of a racer. Then the steam horse is not apt, like his brother of flesh and blood, to be frightened from his propriety by sudden fancies which defy the prudence and skill of the driver. Explosion, if it takes place, will not injure the passengers, for they are in a separate vehicle, and the enginemen may be trusted with the care of their own lives. In daylight, and with good arrangements, travelling in the steam coach, at twenty miles an hour, may be much more safe, as well as pleasant, than in any ordinary stage coach at eight or nine.

The practicability of railways for the transportation of passengers, has been proved beyond question, and, from recent experiments, no doubt can be entertained that every description of article will be eventually conveyed on rails. Even now, many companies in England, owning the most profitable canals in the Kingdom, contemplate draining them, and laying railways on their site. Should they do so, it will be a very strong evidence of the superiority of railways over canals in the transportation of bulky articles.

From the experiments made on the Liverpool and Manchester railway for the purpose of ascertaining the requisite power or weight to move a given body on a level railway, the following were the results: The carriages and weight were moved along the road at various speeds, and with 10, 15, 17, 19 lbs. from which the following proportionate results were deduced: one pound moved 334 pounds, and kept it moving 4½ miles per hour: one pound moved 470 pounds, and kept it moving 3 miles per hour: one pound moved 616 pounds, and kept it moving 2½ miles per hour. On the whole, the results were highly satisfactory; and, from them, it would appear that the work of a horse on a railway, at a slow speed, may be brought to approximate much *nearer to his work on a canal* than perhaps had been generally imagined. Rating the powers of the horse at 150 pounds, the result will be equal to 41 tons, drawn by a single horse at the rate of two and a half miles an hour. Experiments have been made on the Mohawk and Hudson, and Baltimore and Ohio railroads, but the precise results have not been communicated to the public.

The difference in the expense of constructing railways and canals have been variously estimated; some put it down at one half, others at one-third, and again we have seen it estimated as nearly equal; but, from the knowledge possessed by your committee, either derived from actual observation or indisputable authority, they are induced to believe that the cost of a railway is about two-thirds that of a canal through the same route. A single railway, or one set of tracks, with suitable turn-outs, will cost from nine to twelve thousand dollars. A double railway, with two complete sets of tracks, will cost from 15 to 18 thousand dollars per mile. These estimates are for well constructed lines of railways, through a *favorable* country, and do not include any extraordinary difficulty. Every road which is intended to pass over a large extent of country, will be more or less obstructed by mountains, streams, vallies, &c., and in all these cases, the divisions of the road will be subject to change accordingly. The cost of that part of the

Baltimore and Ohio railroad which has been completed with double tracks, consisting of 61 miles, is not precisely known; but the company are of opinion that the average cost, to the Ohio, from the present termination, will fall but little short of $20,000 per mile.

Connected, in some measure, with the cost of railways and their practicability, is the cost of transportation. In making a comparative estimate, we must always remember that time is money, and that the attainment of greater speed and certainty, amounts, in effect, to a reduction of expense. The advantages of a more speedy conveyance are often of greater value than the whole charges of transportation. The actual average cost of transportion is equal to about one dollar per ton per hundred miles, exclusive of the tolls, and the cost of a draft, or traction, upon a level railway, will not exceed a quarter of a cent. per ton per mile. And the above rate of one cent per ton per mile, for the whole cost of transportation, is believed to be entirely sufficient to cover all expenses, and afford a reasonable profit. The daily expense of a locomotive engine now at work on the Manchester road, is as follows: the hire of the engineman, four shillings; firemen, two shillings and six pence; coal, three shillings and four pence; oil, one shilling. Total, ten shillings and ten pence sterling.

Supposing the engine to carry 30 tons, at a rate of ten miles an hour, and to work 12 hours each day, realizing but 10 hours' speed, or 100 miles, makes the cost of traction about one-tenth of a cent per ton.

The improvements that are constantly making in engines, leave the costs of construction entirely problematical, and the same may, in some measure, be said of the way.

The most approved *method* of constructing railways, is on the plan adopted by the Baltimore and Ohio Railroad Company. A line of road is first graded, free from short curves, and as nearly level as possible. A small trench is then formed for each track, which is filled with rubble-stone, on which are laid blocks of granite or other suitable stone, (in the place of wood,) which will square about one foot, and of as great length as can be obtained. The upper and inner surfaces of each track are dressed perfectly even, as well as the ends of the blocks at their joinings. Bars, or plates of wrought iron, near an inch in thickness, are then laid upon these blocks or rails, in a line with the inner surfaces, and fastened to the stone with iron bolts or rivets, entering about four inches in holes fitted to receive them, and at a distance of about 18 inches. The distance between the two tracks, for the wheels, should be about five feet.

The railway cars or carriages are fitted with iron wheels, which, being cast in a *chill,* afford surfaces like hardened steel. Each wheel has a flange, or projecting rim, of about one inch in depth, which runs below the rail-plates on the inner side of the tracks, and which effectually prevents the wheels from leaving the rails.

This mode of construction, both of ways and cars, is now supposed to exceed any other; and when the stone can be obtained to answer the purpose at reasonable expense, no wood is made use of in the construction of ways. This, it will be perceived, renders the work proof against dilapidation, and creates but a trifle more expense.

DOCUMENTS

IN RELATION TO

THE COMPARATIVE MERITS OF CANALS AND RAILROADS.

PUBLISHED BY ORDER OF THE HOUSE OF REPRESENTATIVES OF THE 17TH DAY OF FEBRUARY, 1832, UNDER THE SUPERINTENDENCE OF THE COMMITTEE ON INTERNAL IMPROVEMENT.

EXTRACTS

FROM THE

MEMORIAL OF THE CHESAPEAKE AND OHIO CANAL COMPANY,

(Being Document No. 18 of the 1st Session of the 22d Congress.)

REFERRED TO IN THE RESOLUTION OF THE HOUSE OF REPRESENTATIVES OF THE 17TH DAY OF FEBRUARY, 1832.

The relative cost of the construction of Railroads and Canals, the comparative expense of transportation thereupon, and of their respective annual repairs.

It is believed that these interesting topics of inquiry have recently had new light shed upon them by facts and authorities entitled to the highest confidence.

Some of these, with the conclusions to which they lead, have been already briefly noticed. Others are embodied in the following note, an apology for which, it is hoped, will be found in the intrinsic difficulty, novelty, and importance of the investigations which it undertakes, and the growing anxiety of the public to be correctly informed in relation to the various subjects which they necessarily involve.

In all cases where practicable, the language of the authorities cited will be found to be employed, with a view to insure greater confidence in the conclusions at which the memorialists have arrived.

Extract from the report of the Board of Managers of the Lehigh Coal and Navigation Company, presented to the stockholders on the 12th January, 1829:

"The railroad continues an effective auxiliary to the business of the company, and, being located upon a plane descending in the direction of the load, and requiring no expensive or complicated machinery in its use, approximates, in facility of transit, to *a small canal;* and, whenever an enlarged business shall require the construction of another track, the peculiar advantages presenting for its location will insure its effects to be fully commensurate with the most extended prospects of trade. The report of the engineer will exhibit the progress of the improvements on the Lehigh, and what still remains to be done; from which it will appear that the whole can be completed in the early part of next season, and will then furnish a navigation from Mauch Chunk to Easton, made up of thirty-seven miles of canal and ten miles of slack water pools, having five feet depth of water, and a well constructed towing path the whole distance. The canals are sixty feet in width on the top water line, with locks twenty-two feet wide, and one hundred feet long, and fed, at eight separate points, by substantial dams across the river. These, besides furnishing an ample supply of water for all the purposes of navigation, will also afford important water power in advantageous positions, especially the one at Easton, which has already begun even to attract the attention of manufacturers."

To the annual report, from which the preceding extract is made, is appended the following report of the acting manager, Josiah White:

"That the railroad to the company's mines, notwithstanding it was put up in such an expeditious manner, and was the first made, of such a magnitude in our country, continues to answer the desired purpose, although it has been subject to some modifications and alterations. Since we have reduced the velocity of travelling, from *twelve to fifteen miles* an hour, down to *five and seven miles an hour*, our horses and mules, which, in the former rate, got and kept sick, in the latter continue healthy, notwithstanding their regular daily work is thirty-five to forty-five miles per day; and, so strong is their attachment to riding down, that, in one instance, when they were sent up with the coal wagons, without their mule wagons, the hands could not drive them down, and were under the necessity of drawing up their wagons for the animals to ride in."

"Perhaps some remarks on our experience with our railroad, on which has been transported upwards of 60,000 tons, may settle the question with some of our stockholders, who have doubted the policy of canalling the valley of the Lehigh in place of making a railroad. I, therefore, now give the cost of transportation on our railroad, and also on the Erie canal. Data for the latter, I obtained from the superintendent of the east division of the Erie canal, and also from a gentleman largely engaged for three years in the making of hydraulic lime or cement, and transporting it on one hundred and fifty-two miles of this canal. Both are given, without tolls, or repairs of road or canal.

"*Cost of transportation on our railroad for the year* 1828.

Mules and horses cost - - -	1 1–3 cent per ton per mile.		
Hands - - - - -	1 1–3	do.	do.
Repairing wagons - - -	2–3	do.	do.
Oil for do - - -	1–5	do.	do.
Total -	3 53–100 cent per ton a mile,		

full and one way, and the whole cost divided into the distance one way only.

Cost of transportation on the Erie Canal.

"For boats of forty tons burthen, one cent per ton a mile: full loads one way, and returning empty. Calculated as per the railroad.

"Calculating on same data as above, on a boat of sixty-seven tons, such as will be adapted to the Delaware canal, will cost seven-tenths of a cent per ton a mile; and, for a boat of one hundred and thirty-four tons burthen, adapted to the Lehigh canal, one-half cent per ton a mile; the latter being less than one-sixth the cost per mile, as per our railroad, notwithstanding the favorable circumstances attending that railroad.

"A railroad, well made, is attended with little expense for repairs and decay at first; but all its essential parts begin, though slightly, to decay at its existence, and its decay gradually increases to its final annihilation.

"A canal is attended with expensive breaches, &c. in the first instance, but every repair makes the work better; and most of its constituent parts are as durable as time.

"Our canal, it is believed by our engineer, will be passable by the seventh month (July) next. It is calculated for boats of one hundred and thirty to

one hundred and fifty tons burthen. All the locks, aqueducts, culverts, &c. are laid in hydraulic lime. The ponds connecting the canal are cleared out in the channel fifty feet in width, and five feet deep: and all the tow-paths along them are faced with a permanent slope wall. In the whole line, I know of no part on which money is expended for ornament; but, inasmuch as we were sure of a large transportation on it, money has been expended to make it substantial, that might have been avoided, if the desire had been more to come within the original estimate of the engineer than to have made a substantial and permanent work.

"In the dryest weather of last autumn, our engineer, Canvas White, was on the summit between the Nescopeck and Lehigh, and, at the Lehigh, where it was proposed to take the water out for the supply of the canal to Nescopeck and the Susquehannah; and his opinion was given, that there is an abundant supply of water for the summit; and, since then, Mr. Robinson, a skilful engineer, appointed by the State commissioners to examine those grounds, for a canal or railroad from the head waters of Schuylkill and Lehigh, or Broadhead creek, to the river Susquehannah, has examined those grounds; and I learn that the result of his examination is, that, of all the lines proposed, *there is but one* adapted for a canal navigation, and that one is by the Nescopeck to the Lehigh; and here, by resorting to a tunnel of only one hundred and seventy-five poles in length, and a dam only ten to thirteen feet in height across the Lehigh, at the mouth of Bear creek, the river Lehigh will flow into the summit. When it is recollected that it is the *only* line for a water communication north of the Blue mountains, that can connect the Susquehannah with the Delaware and Philadelphia, and that the produce of the *west branch* of the Susquehannah can get as cheaply this way as any other, and *all* on the north branch of the Susquehannah, cheaper to Philadelphia, and thus be tributary to the Lehigh canal, and the Delaware division of the State canal, the stockholders of this company, and the public at large, will know, ere long, how to appreciate it. The Nescopeck and Lehigh canal is calculated to correspond with the Delaware section, for boats of sixty-seven tons burthen, *and will cost for transportation, from Berwick to Mauch Chunk*, from the best data I can get, *about one-third as much per ton a mile as on our railroad;* this, added to the advantages of a *continuous voyage in the same boat*, and with the *same superintending hands*, (and *no trans-shipment*,) from the extreme ends of the Susquehannah canal to Philadelphia, will, I presume, settle public opinion on the manner of passing the ridge of land between the waters of the Susquehannah and the Delaware.

"All which is respectfully submitted.

"JOSIAH WHITE, *Acting Manager.*"

Philadelphia, 1*st mo.* 12*th,* 1829.

Extracts from the report of the Board of Managers of the Lehigh Coal and Navigation Company, for the year 1830, *and the Acting Manager's report:*

"The length of our line of improvement is 46¾ miles, and has cost, including the whole of the river improvement, from its commencement as a descending navigation, to its final completion, about $1,558,000; the distance being divided into 36¾ miles of canal, and 10 miles of pools, with a tow path throughout the line."

From the Acting Manager's report of 1829.

"We have made some very satisfactory alterations in the railway, for the purpose of preventing the early decay of the timber, and jolting of the wagons. We now run the wagons at the average rate of about six miles an hour, and find this motion produces much less wear, both of the wagons and road, than a greater velocity. I have demonstrated to my satisfaction, that the wear and tear of the road and wagons is in proportion to the motion; and that, in the end, a motion exceeding twenty miles an hour (which we tried in the first months of our business) will make the transportation on railroads more expensive *than on our graded turnpike* on which the rails were laid."

In addition to the information derived from the published documents and reports of the Lehigh Coal and Navigation Company, it is deemed proper to insert in this note the following essay in the Mauch Chunk Courier, from the pen of the highly respectable superintendent of that work, sustaining the views of the comparative advantages of railroads and canals which his official duty had prompted him to communicate to those in whose service he has long been engaged; and whose confidence he is known to have possessed, in an eminent degree.

To the Editor of the Mauch Chunk Courier.

A friend handed me, a day or two since, the "Paterson (N. J.) Intelligencer," dated 7th April, and called my attention to a long article, signed by John I. Sullivan, civil engineer, wherein I am made to appear the enemy of the public improvements now going on in our country. It would be a poor compliment to human nature for me to change at this time of day, after twenty years' personal devotion to works of a public nature, and twice jeopardising my whole estate in promoting those improvements, and now take a contrary course.

We began our railroad early in January, 1827, and finished in May following. Up to this time, we transported on it more than 100,000 tons. Its entire length is nine miles, single tracks; its branches at the ends and sidelings, four miles more. The elevation of the road, from the head of the chute to the summit, is 767 feet, in a distance of eight miles, being an average of ninety-six feet to the mile. We have not had a week's interruption, from casualty, since it was finished; so that it may be called a practical road from its completion. The first two months' use of the road, our wagons moved fifteen and twenty miles an hour, as the men who had charge of their descent were anxious to get through the route as soon as possible, to avoid the fatigue of holding them in check by the breaks. We soon perceived our utter inability to keep the wagons repaired without reducing the speed, or be subject to cost and repairs greater than the gains made over the good turnpike we had abandoned; besides, the tremulous motion occasioned by the wagons going at those rapid rates ground the corners of the coal into powder, which enveloped the driver in a continual cloud of dust.

Our railroad was new when we travelled at the high speed, and, although not so perfect as it might have been made, I presume it was as evenly made as those which are made more perfect in other respects, in the first instance, would be, after one year's wear and tear from 100,000 tons per year going on them, at the rate of 15 or 20 miles an hour. Thirty years ago, the rail-

roads in England, and, until very lately, had their flanges on the track of the road, or most of them in that way; and, as a consequence, were always liable to be covered with dust, dirt, &c. : ours is of the modern construction, and we have adapted it to ride the horses down, so that they perform two ordinary days' work in each day. The only difference between our road and the most modern one in England, is, that their work is put together more evenly and stronger, to carry their locomotive engines, which weigh two or more times as much as passes on our road. Our road is graded so as to have such a continued descent from the summit down, as for the wagons to descend on all parts of it by gravity. When they began to pursue this mode in England, I know not: ours was the first of the kind we had any knowledge of, and the English have not improved on it.

I am too good a republican to fear responsibility when I see my way clear. I should suppose the men of science in England would be governed in their knowledge of facts, the same as in other places. It is but a thing of yesterday, they had any knowledge of wagons going at the rate of twenty to thirty miles an hour; and they had no experience to test the consequences; to get these motions has caused them unusual efforts. The case was different with us; we had a difficulty to go slow; and we thought we had exploded the economy of a rapid motion before the English began theirs. I believe that if a railroad was made perfectly even, and could be kept so, that the wear and tear would be very different from what is the every day's experience. I am so unaccustomed to see perfect articles, that I sometimes doubt of their being such, and they are hardly to be expected on the track of long roads, exposed to all kinds of weather and casualties. I have never noticed a long bar of wrought or cast iron of an even degree of hardness, the whole length, on all its sides.

I had an interest in a wire factory at the falls of Schuylkill, which made half a ton of wire per day—we cut the bars into from five to eight pieces, (and our iron was the best we could select,) and it was a very rare thing to find the bars so evenly tempered as to bear reducing this small quantity without breaking, and, generally, in several places.

With the utmost skill and experience of our mechanics, we do not find them to bore a steam engine cylinder perfect; the pistons all require packing to prevent the escape of steam. I never noticed a wheel cast perfectly true; we cast ours in, (turned,) but they do not come out perfectly correct; and if they were cast or turned true, it is as difficult to wedge them on perfectly correct: so difficult is the attainment of perfection on this side the grave. With these difficulties before us, I will take it for granted the wheel of the cars is 1-16th of an inch out of truth, and that they are three feet in diameter: to go thirty miles an hour, would require them to revolve 278 times per minute, and the wagon and load weighing four tons, is one ton to each wheel: each wheel of the car strikes the road with a weight of one ton 273 times a minute, faster, I presume, than any man can count: besides this evil, the materials which compose the heaviest item of expense are of a perishable nature, whether used or not, and wear and tear proportioned to use. These are some of the reasons why I believe a road will not be made perfect; and, if so made, will not last interminably long, like the materials in a canal.

I am asked, if I could, on my experience, check the spirit of investigation and enterprise that is abroad in the country? I answer certainly not the former, but, as to the latter, I think it only valuable when

governed by prudence, and then only it is invaluable. I recollect very well when the coal trade, and even the making inland navigation in our country was in disgrace in the eye of the public; but neither is so now. The public is now extra hot in the same degree as it was extra cold formerly. The coal trade is now large, as well as respectable, in the opinion of the public; but there are no doubt ten times as many in the trade, as many canals and railroads talked of to transport coal to market, as there are markets for the article. Can this, then, be an enterprise wanting a spur? or what can the numerous canals and railroads contemplated be worth, if made? A canal has two advantages over a railroad, besides the economy of using. Their number of sites are known, and they are limited by water; and if they are made faster than the wants of the country, occasioned by a feverish state of the public mind, or by an error of judgment, they do not decay, whether used or not, except the lock gates, and wood work, of which, there is very little since hydraulic lime has been brought into use. I believe that a railroad can be made strong, solid, and true enough, to not only admit of a speed upon it of six miles an hour, but even sixty miles an hour, for a short time; but I do not believe there will be economy in going more than six miles an hour with heavy loads, unless it is with passengers, valuable goods, &c. which will bear heavy tolls. Our company have no reason to dislike railroads—ours has undoubtedly saved $500,000 already; but, by our canal, we now go an equal distance at one-fourth the cost of the railroad. But a canal cannot be made to the mines, so we resort to the next best thing.

J. L. Sullivan says, "the Stockton and Darlington road is certainly kept in the best repair, and is the best constructed railroad now in operation in England. Cast rails have been tried, but malleable rails are principally used, and decidedly preferred by the proprietors."

This road has been made about five years, and, since that time, they have condemned the old plan. But what, say they, of the best English road, in October last? The London Mechanics' Magazine, of Oct., 1829, page 141, has the succeeding observations: "the speed of the engines has been increased on the Darlington road, by substituting wheels of four feet diameter instead of three feet; but these, working on the plane bars, cannot be case-hardened, for fear they would turn round when they have a hard pull; consequently, they are made of soft iron, which, from the immense weight of the engine, wears them in grooves the width of the rail, and twists them sideways, which keeps men, incessantly on the line, setting them straight."

So we find thirty years' experience is condemned; and all that we now have worthy of our notice, are the experiments of a few days or hours, and these are leading brother Jonathan by the nose. Thus much for the best railroad in England. But still, I *allow* they may make them stronger, although not so as to prevent those effects in a greater or less degree, if a speedy motion is resorted to, particularly with a locomotive engine, as the stress necessary to pull the load impinges through the wheels on the road, and thus the joints of the road are pulled together between the wheels of the engine and the cars, so as to keep up an incessant action in the rails. J. L. S. gives us credit for constructing our railroad at $1500 per mile; no one has the company's authority for this; our statement was $3,050 a mile, and most of it was laid on an old turnpike and single track.

The Manchester and Liverpool railroad is not a fair comparison for other railroads; neither is the novelty engine justly cited, as a standard, by

which others are to be judged. The quantity of valuable merchandise passing between the two towns is said to be 1200 tons daily; and the passengers only, it is supposed, will produce $111,112, per year. The whole length of this road is but 32½ miles. They can, therefore, afford to construct it in a manner approaching as nearly to perfection as possible. The Novelty has had but a limited trial; our last accounts made it amount to a period of about six hours. It would hardly be prudent to invest millions on a thing that was not as durable as Jonah's gourd. It may do well: it is a neat affair enough; but it would be safer to wait a year or more before we pronounce it entitled to full faith, or consider it of such amazing utility, with no other data for our decision than the result of six hours' experimenting. Its boiler carries but 36 gallons of water, which is the main cause of its lightness. To produce the requisite steam, the evaporation must run rapidly from this 36 gallons of water; and if the supply pump does not correspond with the making of the steam for a few moments, a blow up is the inevitable consequence.

To compare railroads and canals by dollars and cents, as far as we have practice and experience for our guide, will, no doubt, be coming nearer the point the public desire to attain. And whether it is gratifying to some or not, we, I trust, will all find that economy in the use of the improvements resorted to, is the one thing needful, which the public at large is most interested in having accomplished.

The annexed calculation is estimated from the cost, &c. of the Mauch, Chunk road. But that part of it only, from the summit of Mauch Chunk being eight miles, descending the entire distance, and the whole owned by a single company, (so that we are exempt from the interference of neighbors,) it is presumed can compare in its use with the minimum cost of a first rate railroad under the most favorable circumstances.

Estimate of the repairing, &c. of the perishable part of the railroad with double tracks.

For one mile, 20 tons plate iron, cost for iron and laying down, $2,000; last, say 20 years		$100 00
Wood for rails and sills, 126,720 feet at $15	$1,900 80	
Carpenters' work say	1,900 80	
	$3,801 60	
$3,801 60 last six years ÷ 6 =		633 66
One man repairing road to each mile, 250 days		250 00
Cost of repairing one mile per year		$983 66

If the transportation be 100,000 tons, it is, say one cent per mile; and the repairs increase with the increase of the use of the road.

Wear and tear, or renewing of the railroad wagons, they lasting 4 years.

42 wagons (load a boat) cost	$4,200
7 mule wagons	350
	4,550

Last four years, is $1,137 50 per year.

225 days in the season, and 32 cwt. each wagon going two trips a day, is 134 tons 8 cwt. a day, or 30,240 tons a year ÷ 1137 50 = 3.76 ÷ 9 = 42.109

Making daily repairs to wagons, three hands, 225 days -	$ 675
Materials for repairs - - - - - -	1,350
Annual cost of current repairs - - - -	2,025

2,025 ÷ 9 miles = $225 ÷ 30,240 tons is per ton a mile, 74-100 of a cent.
Total repair of wagons 1 16-100 cent per ton a mile.

Cost of hands and animal power from the summit to the end of the road, descending all the way:
28 mules go two trips a day, and draw up 42 coal and 7 mule wagons (to carry down the mules) each trip, &c. going 32 miles a day, the 42 wagons, each carry 32 cwt. coal each trip. Total 134 tons.

28 mules at 33 cents a day, - - -	$9 24
4 drivers, 90 do - - - -	3 60
	12 84 ÷ 134 = 10 cts.

for 8 miles, or $1\frac{1}{4}$ cents a ton a mile.

This $1\frac{1}{4}$ cent a ton a mile is the *nett cost*, without any contingencies; the cost last year was $17\frac{1}{2}$ cents for 8 miles, being, say 2 cents. The difference between the two was made up of the superintendent of the railroad, hands assisting to provide for the animals, lost time through the season, keeping animals in the winter, &c. making the *whole* cost, at a close estimate, 4 16-100 cents a ton a mile, exclusive of interest account and grease.

Canal estimates of transportation and repairs of canal.

The boat carrying 75 tons makes a trip loaded, down to Easton, 46 miles, and returns empty in $4\frac{1}{2}$ days.

3 men at 90 cents.	$=270 \times 4\frac{1}{2}$ days =	12 15
2 horses and rope, 85 cts.	$=170 \times 4\frac{1}{2}$ days =	7 65
Boat, 70 cents a day,	$4\frac{1}{2}$ days =	3 15
(Boat cost $700, and last 1,000 days)		22 95

$22 95 ÷ 75 ton = 30 60-100 ÷ 46 miles = a ton a mile $66\frac{1}{2}$-100.

Wear and tear of the canal.

The lockage from Mauch Chunk to Bristol, in tide, is 524 feet, which, with 8 feet lifts, is 66 locks, distance 106 miles; 66 locks will require their gates renewed every 10 years, and the cost of a set of gates, say $500 × 66 = $33,000 ÷ 10 for their duration, is per year,

$3,300 ÷ 106 miles, per mile, - - - -	$31 13
52 hands, 250 days, being 1 hand to 2 miles, repairing, (after 8 years' duration) is, a mile, - - - - -	125 00
	156 13

100,000 tons ÷ $156 13-100 = $1\frac{1}{2}$ miles, or 15-100 a mile, which, added to $62\frac{1}{2}$-100, makes the total cost of transportation by canal, including wear and tear of canal, $81\frac{1}{2}$ 100 cents a ton per mile, exclusive of interest.

Our present cost of transportation on our canal, in *rough arks*, is, per ton per mile, - - - - - -	1 cent
To which add the wear and tear of canal, as above, do do	15-100
Total cost, *at present*, per mile, per ton, - -	1 15-100

Hence, it appears that our canal, used in the ordinary way, will cost less than one-fourth of a first rate railroad.

It may be observed, that I have not noticed the cost of lock gate keepers; this was omitted, because the water power passing from one level to the other to keep them up, will produce a revenue greater than their pay.

There are two items, not heretofore taken in account, that will lessen the cost of transportation on the canal, where there is plenty of water as in the Lehigh and Delaware, viz. one is, that, as *the freight is mostly downwards, half the power may be saved by letting a current pass down the canal;* the other is, that, *by using propellers*, and having two locks at each lift, one for ascending and the other descending, *we can save all the animal power by substituting water power*, and one-third of the hands; thus reducing the cost of transportation about one-half. Our railroad friends must allow us to avail ourselves of improvements in canals, if they take that course in railroads. But, in making my estimates, I have endeavored to consider what expenses *have occurred*, rather than what *may* occur; for many of our supposed improvements oft times prove injurious, rather than beneficial, to those who have been at the trouble and expense of making them.

JOSIAH WHITE.

5th mo. 20, 1830.

The following are extracts from letters of Mr. White, to a distant correspondent:

"MAUCH CHUNK, *3d mo. 5th*, 1830.

"Railroads are a great improvement on turnpikes; but, in my opinion, are vastly inferior (particularly as a public work, and in a republican country) to canals, both as to convenience as well as economy. A canal is accessible everywhere, a railroad nowhere, (without interrupting the current of wagons,) except by an arrangement for turning out; and the more turn-outs are made, the greater the casualties. By canal, every boatman may choose his own motion, within the maximum motion; by railroad, every traveller must have the same motion, or be subject to turn outs; which, as I have said, have their casualties. The motion of twenty and thirty miles an hour on railroads will be fatal to wagons, road, and loading, as well as human life.

"We have a distance of eight miles from the mines, with a descent of seventy to one hundred and twelve feet in a mile. The velocity of the wagons would exceed thirty miles an hour, if not checked. Our first two months' use of the road was fifteen and twenty miles an hour, which would have soon ruined both road and wagons, and, I am persuaded, was then dearer than the turnpike we put our rails on.

"Our present motion, say of six miles an hour, is very satisfactory: and makes the railroad an immensely valuable appendage to our coal business. Wet or dry, we go on it; moist and wet weather, which ruins turnpikes, makes the wagons run freer on the railroad; snow, however, is an impediment. Our wagons will not run down from the mines, by gravity, in a snow storm; the snow packs on the road. In such weather, as well as in sleety weather, we cannot use the break, as it slips too freely to produce the necessary friction to check the wagons.

"I think it rather fortunate for society, that railroads are not of equal value to canals, for a railroad can be taken anywhere; and, consequently,

no improvements would be safe on their line: for the moment the improvement succeeded, it would be rivaled, so as to destroy both, &c., whereas we know the line and limits of our canals, by the supply of water, and graduation of the ground; so that all improvements thereon are safe against the undermining of rivals. I should consider, that, if the railroads superseded canals, they would, for the above reasons, render the tenure or value of property as insecure as it would be if without the protection of law."

"MAUCH CHUNK, *3d mo. 25th,* 1830.

"Thee, no doubt, has observed the last accounts of the "Novelty" locomotive engine on the Manchester and Liverpool railway, stating that the fuel (at ten shillings sterling a ton for coke) costs but thirty-seven shillings sterling to carry a ton of goods round the world; and that the owners offer to make engines to weigh five tons, and draw one hundred tons, that shall not consume more than about one-third of a mill, our money, a ton a mile. This, no doubt, will be received as a well settled experiment in favor of railroads, and against canals.

"I suggest, if this engine is of the superior order represented, that it is *equally adapted to canals*, by having a less power, and proportioning it to the load it has to draw. Our canal can carry boats of one hundred and forty and one hundred and fifty tons. Our State canals generally carry boats of seventy-five tons. This power can be applied as advantageously on the canals as on the railroads, by having light rails on one or both sides of the canal for the wheels, which drive or draw the boat to run on, and keeping the engine on the boat: by which means, the engine will, no doubt, be made to last three times as long as if on a railroad, from the incessant jarring of the latter. Thee will perceive, by the tables in the books on the subject of railroads, that, at two and a half miles an hour, the effect from the same weight is 55,500 pounds by canal, and 14,400 pound by a level railway; so that the same engine would propel three and a half times as much on a canal as on a railroad, and, of course, save two-thirds the fuel, and the same proportion nearly of the power of the engine, in addition to its increased durability.

"With regard to engines on railroads, moving with equal weight with indefinite velocity, it is proved by us, and on the Liverpool railway, to be a false theory; the motion invariably was reduced by adding to the weight to be pulled; and the wear and tear, no doubt, is as the velocity, the weights being equal."

It is not deemed improper here to insert the opinion of the oldest and most eminent civil engineer in the United States of America, who has served more than fifteen years in the best school for all practical science, that of experience.

Extract from a letter of Benjamin Wright, of New York, dated October 31, 1831, *in reply to a letter addressed to him by the President of the Chesapeake and Ohio Canal Company.*

"The Delaware and Hudson Canal Company own 108 miles of canal, on which there are 110 locks; and also 16 miles of railroad, on which there are 5 steam power stationary engines to draw up coal 800 feet, and 3 self-acting planes to let down coal about 700 feet.

"The board of directors were not satisfied that all these works, in mining coal, in transporting over the railroad, and along their canal, were managed with that rigid and strict economy which the competition in the article made useful and necessary for the interest of the company, and they appointed myself and one other gentleman to go through all their work, and examine into every expenditure; of what had been, as well as what, in our opinion, ought to be done, to economize in mining the coal, in transporting over the railroad and along the canal, to tide water. We had full powers to call on every man in their employ, and examine into every expenditure, in all its details, so as to report what would, in the present state of things, when the railroad and canal were both in good order, be a fair and proper charge on the coal.

"We spent 20 days in this duty, and made our report to the board of directors. We found that the expense on the railroad, not including any toll, would be about 3¼ to 3½ cents per ton per mile; and, on the canal, without toll, one cent to one cent and two mills per ton per mile. We took great pains to get every information on all points having the least possible bearing, and I have no doubt the comparison is a fair one for *this canal* and *this railroad.* Perhaps railroad advocates may say that this is not a fair sample of railroad to compare with. In so far as it is loaded with 5 steam engines, as stationary power, to draw up coal, and 3 self-acting planes to let down, it has an extra charge upon it; but then the great number of locks on the canal causes detention and increases expenses. As the result came out so nearly like Josiah White's statement on the Mauch Chunk canal and railroad, as published in the Intelligencer some two years ago, and proved the correctness of that statement, and as their railroad was not subject to stationary power, I consider the comparison a fair one on the whole."

Letter from the same to the same, of subsequent date.

NEW YORK, *December* 17, 1831.

DEAR SIR: You ask me my opinion of the comparative advantages of canals and railroads as applied to the Potomac valley, and the great plan of a connection between the eastern and western waters?

This question presents a great field for argument, and no doubt much may be said on both sides. I will, however, give you my own views as applied to the locality in question.

I am decidedly in favor of a canal in preference to a railroad, and more particularly for that part between tide water and Cumberland, and between Pittsburg and the mouth of Casselman's river. As to the intermediate space, a question might arise whether the great amount of lockage, and the long tunnel, would, *at present,* justify the expense of a canal in preference to a railroad. Time, and the probable prosperity of the country, when a dense population should cover it, along the line and beyond it, would probably justify a continuous water communication over and through the mountains, in half a century or less.

These are the outlines of the results of my own mind as applied to this case.

I am probably, at this time, in a minority in the United States as to my opinions of the comparative advantages of canals and railroads. I

have very little doubt I shall be in the majority before two years more are expired.

The public mind does not, in my opinion, take all circumstances and bearings into consideration, when they undertake to give opinions. They hear of the Manchester and Liverpool railroad, and of the great effects and results produced on it, but they do not know the whole of the expenditure as well as the whole receipts. In this case, as well as on the Baltimore railroad, we are kept in the dark about wear and tear, and shall be for some time to come.

I admit that, for passengers, a railroad is a useful and rapid conveyance; but, in our country, and particularly in the Potomac valley, the passengers are a small matter compared with the products of the soil; the forests and mines. We know that the Erie canal has more tonnage, in lumber, than all other tonnage on it, and, for the article of square timber alone, this year, the rafts of it, which have passed, (being rafted only 14 feet wide, so as to pass locks) would, if put together, stretch 50 miles. This is an article of first necessity, and could not come as cheap, if at all, on a railroad as on a canal. I may add boards, also, which are brought in boats much better than on railroad wagons.

But the great advantage a canal will always have over a railroad consists in the little mind or thought that is required to use it. Any man or boy can navigate a canal, but it requires much more mechanical skill to manage on a railroad even by horse power, and many times as much more to manage a locomotive. I consider a long line of railroad, where the power is often changed, as it must necessarily be, in passing from Baltimore over the mountains, as a very complicated machine; as liable to have its parts get out of order, at a distance from any work shop, where repairs can be made; and as being odious in this country, as a monopoly of the carrying, which it necessarily must be. A canal, on the contrary, is open to any man who builds a boat, and he may travel or stop, when and how he pleases, if he does not interrupt the passing of others.

In short, I place a railroad between a good turnpike and a canal. I consider the expense of transportation, from the little experience I have had, to be about in the proportion of three to one, between a canal and railroad, in favor of the former, without tolls on either. All these opinions are the conclusions of my own mind, from critical examinations of works of both kinds, and all the light I have been able to obtain on the question. I could say much more, but I presume what is said above is sufficient is answer to your question.

With much esteem, I am, dear sir, your obdient servant,

BENJ. WRIGHT.

Gen. Mercer.

Letter from John Bolton, late President of the Delaware and Hudson Canal Company, to the Editor of the Savannah Georgian.

New York, *July* 21, 1831.

Dear Sir: I perceive that some of the papers are endeavoring to arouse the people of Georgia to a sense of the importance of artificial means of transportation between the interior of the State and the coast. Both interest and good will induce me to wish them success, and, were I a young man,

I should like much to take a part in executing any work that should have a favorable bearing on Savannah. A six years' experience in the construction and operations of the works of the Delaware and Hudson Company would give me some advantages; but, as it is, I can only offer my good wishes and any useful information that may be in my power. From the articles I have seen, I perceive, with some regret, that they entirely overlook the great natural advantages that Georgia has over most of the States in the construction of canals, and recommend railroads; which are the only resource of those who do not possess facilities for canals, and who, consequently, endeavor to make the public believe that they are superior to canals. In this they have succeeded to some extent for the present; but, having some experience of both, I am not among the converts to this new system. I give it a place between turnpike roads and canals, and feel a confidence that time will confirm this order; and this only in cases where the amount of transportation will justify the expense of a railroad.

In a late report to the proprietors of the Liverpool and Manchester railroad, it is stated that they had reduced the expense of transportation from 15*s*. per ton by canal, to 10*s*. by railroad, for 32 miles. This reduced rate, at 7 pet cent. exchange, is $2 37½ per ton. On the Erie canal and Delaware and Hudson canal, the highest rate on merchandise, including toll, freight, and receiving and forwarding, is 5 cents per ton per mile, $1 60 for 32 miles; on flour, and on other articles of small value, it is still less. Flour does not exceed, for long distances, 3 cents per ton per mile, making only 96 cents for 32 miles. On the Delaware and Hudson canal, a boat carrying 30 tons costs $400; 5 per cent. per annum, will keep her in repair. It requires 12 wagons to carry the same weight on the railroad, cost $1,400, and the repairs will probably be from 15 to 20 per cent. The annual repairs of the canal cost about $400 per mile; the railroad about $1,500 per mile. The canal is getting better every year, the railroad worse. The railroad of the Delaware and Hudson Canal Company passes over a rough uneven country, and has eight inclined planes.. The wear of machinery and ropes, on these planes, is very expensive, and bears a greater proportion to the length of line that would be found in Georgia below the mountains. I have, however, no doubt that the annual expense of railroads will be found to be greater than is generally estimated.

The greatest advantage claimed, by the advocates of railroads, over canals, is in the rapidity of travel; and the Liverpool and Manchester railroad furnishes the grounds for this claim, as the results of the Erie canal have furnished data on which to found similar projects; and both are equally exposed to disappointment. The Liverpool and Manchester road has cost $118,000 per mile, whilst, in this country, we estimate our railroads to cost from 5 to $12,000, and nothing is now better ascertained than that strength and firmness must be in proportion to velocity of movement; and that, to avoid the expense and delay of inclined planes, hills must be cut down and valleys filled up. These requisites cannot be attained without great expense, except in locations peculiarly favorable, but strength and firmness are indispensable in any location. Besides, there is one advantage claimed in favor of railroads in this quarter, which is not applicable to the South. The waters diminish here at the period of greatest business: the reverse is the case at the South. Here also canals are shut by ice in winter, and then it is believed railroads will continue to be used, but, from my experience, the expense and difficulties will be found to be much enhanced; and where inclin-

ed planes are used, so much so, as to forbid their use upon a calculation of profit. I write from no other motive than good will towards my fellow-citizens of Georgia. I wish them prosperity, and should therefore regret to see them carried away by the fashion or mania of the day.

The above letter appeared in the Savannah Georgian of the 25th of August last. Its author is John Bolton, esq. of New York, late President of the Hudson and Delaware Canal Company. The letter, as the paper observes from which it is copied, contains lessons of practical knowledge worth a thousand of the wild theories of untried experiment.

Extract of a letter from John Bolton, Esq. of New York, late President of the Hudson and Delaware Canal Company, to the President of the Chesapeake and Ohio Canal Company, dated New York, Dec. 17, 1831.

"Having resigned my station in the Delaware and Hudson Canal Company early in April last, the document to which you refer is not accessible to me. I can, however, repeat on the subject, what I stated to Mr. Habersham, that the Delaware and Hudson canal is 108 miles, the railroad 16 miles; that the toll, on coal, on the canal, was revised, I think, in January last, and fixed at $1 50 per ton for the whole distance, and on the railroad, at 50 cents per ton; that the expense of repairs and superintendence on the canal was estimated, for 1831, at about $400 per mile; and on the railroad at rather more than $1,500 per mile; that the railroad has 8 inclined planes, 5 worked by steam engines, and three by gravity; and the canal has 110 lift locks, and 3 guard locks, used also as lift locks in high water; and that the form of country and obstacles to be overcome on the line of railroad are not more unfavorable for a railroad, than the canal line was for a canal; that a section of canal on the Delaware river, of 1 mile and 8 chains, cost full $40,000, and there are several shorter sections proportionably expensive. For the rest, I must beg to refer you to my second letter to Mr. Habersham. I may, however, add, that I corrected, on more recent information, the error in my first letter as to the cost of the Liverpool and Manchester railroad: I think I made it out to be $149,000 per mile. I have no specific information of late date in relation to railroads in England, nor have I seen lately any quotations of the value of canal and railroad stocks in England. There is, however, no doubt on my mind that railroads in England are getting the station which I long since assigned them, that is, between turnpike roads and canals. Gentlemen from that country say they are less popular than they have been; that, in fact, the mania is wearing off by reason of the great expense of maintaining them, and the machinery used on them; and it was recently stated that a project got up in Birmingham, had, by a resolution of the contributors, been suspended for six months, for the purpose of seeing the results of those then in operation."

Extract from the last annual report of the Pennsylvania Canal Commissioners, to the Legislature of that State, dated December, 1831.

"The board have, in like manner, been frustrated in their calculations, by some of the contractors for laying rails abandoning their contracts. The difficulty of procuring stone blocks of a suitable quality has proved to be much more serious than was at first anticipated, and the consequence has

been a retarding of the work, and an increase of its cost over former estimates. The present estimate of the cost of the whole work, when completed, is $2,297,120 21, being equal to $28,173 63 per mile.

"The work is constructing upon the principles of the latest improvements in railroads, and in the most substantial manner; and, although the cost of it may appear to be large, yet, when the quality of the work, and the sum required to construct similar works elsewhere, are duly considered, it is, perhaps, as reasonable as ought to be expected.

"The graduation and masonry alone, of the first twelve miles of the Baltimore and Ohio railroad, cost $46,354 56 per mile; and that whole road, now under contract, (being 71 miles upon the main stem of the road with *double tracks*, and a branch of 3½ miles to Frederick with a *single track*, one-third of the whole road to be laid with stone rails, and the remaining two-thirds with wood,) is estimated to cost $1,906,853, or $27,228 per mile. The company, in their late report, state "that it required 6½ months to lay down 6 miles of stone track," and "that the cost of laying with stone has been underrated in every instance." The celebrated Liverpool and Manchester railroad, in England, which has been the principal cause of creating an excitement in public opinion favorable to that species of improvement, cost the enormous sum of 117,000 dollars per mile.

"While the board avow themselves favorable to railroads where it is impracticable to construct canals, or under some peculiar circumstances, yet they cannot forbear expressing their opinion, that the advocates of railroads, generally, have greatly overrated their comparative value. To counteract the wild speculations of visionary men, and to allay the honest fears and prejudices of many of our citizens, who have been induced to believe that railroads are better than canals, and, consequently, that, for the last aix years, the efforts of our State to achieve a mighty improvement, have been misdirected, the canal commissioners deem it to be their duty to advert to a few facts which will exhibit the comparative value of the two modes of improvement for the purpose of carrying heavy articles cheaply to market, in a distinct point of view.

"Flour is now carried, by the canal, to Philadelphia, from Lewistown, 211 miles, for 62½ cents, and from Harrisburg, 150 miles, for 40 cents a barrel; and gypsum is taken back, for three dollars a ton, to Harrisburgh, and five dollars a ton, to Lewistown; therefore the freight (exclusive of tolls) is, downwards, 14½ mills per ton per mile, and, returning, 7 mills per ton per mile; or, on an average both ways, one cent and three-fourths of a mill per ton per mile for carriage.

"On nine miles of railroad at Mauch Chunk, and on ten miles of railroad between Tuscarora and Port Carbon, the carriage of coal costs 4 cents, and the toll on the latter road is a cent and a half per ton per mile.

"The comparison will then stand thus:

On ten miles of railroad between Tuscarora and Port Carbon:

Freight per ton, - - -	40 cents.	
Toll on coal per ton, - -	15	
	—	55 cents.

On ten miles of the Pennsylvania canal:

Freight per ton, - - -	10¾	
Toll on coal at half a cent per ton per mile,	5	
	——	15¾
		——
		39¼

"Being 39¾ cents difference in favor of the State canal, on each ton, for every ten miles of transportation.

"The following table will exhibit the relative useful effects of horse power when employed on common roads, on turnpike roads, on railroads, and on canals.

Four horses will draw, in addition to the weight of the carriage or boats containing the load,	Weight of freight transported.		Number of miles per day.	
On a common road, in a wagon, -	1	Ton.	12	Miles.
On a turnpike road not exceeding five degrees of inclination, in a wagon, - -	1½	"	18	"
On a railroad having a rise and fall of 30 feet (or one-third of a degree) to the mile, in 8 cars,	16	"	27	"
On the Pennsylvania canal, in two boats,	100	"	24	"

"The introduction of locomotive engines, and Winans' cars, upon railroads, where they can be used to advantage, will diminish the difference between canals and railroads in the expense of transportation. But the board believe that, notwithstanding all the improvements which have been made in railroads and locomotives, it will be found that canals are, from two to two and a half times better than railroads, for the purposes required of them by Pennsylvania.

"The board have been thus explicit, with a view to vindicate the sound policy of the commonwealth in the construction of her canals; yet they again repeat that their remarks flow from no hostility to railroads, for, next to canals, they are the best means that have been devised to cheapen transportation. They are valuable in many situations, and particularly along courses of great thoroughfare, which will bear the expenses of their construction. They can be made to carry the United States' mails and passengers, and also light valuable goods, where *time* is of more importance than cost of transportation."

"*Alleghany Portage Railroad.*—The length of railroad, from the east end of the lower basin at Hollidaysburg, to the west end of the basin at Johnstown, is 36 miles and 221 perches; but, between the head of the basin at Johnstown, and the upper basin at Hollidaysburg, the distance is only 35 miles and 310 perches."

"A space one hundred and twenty feet wide, has been staked out and appropriated to the use of the commonwealth the entire length of the railroad. The reasons which governed the board in occupying so much ground, are these: It was necessary to clear off the tall heavy timber of the mountain, for at least 60 feet on each side of the centre of the road, and hereafter the incalculable trade of the Mississippi basin and the lakes, will require an additional number of tracks over the mountain; hence, prudence seemed to dictate the propriety of appropriating to the use of the State, as much ground, as may hereafter be required, while it is at present of very little value."

"The bed of the road is graded 25 feet wide, for a double set of tracks."

"The railroad when completed, with a double set of tracks of stone and iron, with the necessary machinery, the whole executed in the best manner, is at present estimated to cost $1,271,718 18. The amount of work done on the 1st day of November was $75,195 96, of which $63,984 84 has been paid, and $11,211 12 is retained."

"It may be proper here to remark, that the cost of the work yet to be

done has been estimated at the contract prices, with a liberal per centage added to cover contingencies; and, although estimates have hitherto proved little else than their own fallacy, yet the board believe the above is ample, and may be relied upon."

The Pennsylvania Canal Commissioners, after saying in their report of the *estimates* with which they had hitherto been furnished, that "*they have proved little else than their own fallacy*," speak of the Columbia and Philadelphia railroad, as having had work done on it of the value of 231,000 dollars; and acknowledged that, so far as the work has gone, it has cost more than the estimates. The present estimate of the whole work, they state "to be $2,297,120 21, being equal to $28,173 63 per mile."

Of the Alleghany Portage railroad, between the Juniatta and Conemaugh rivers, in length about 36 miles, upon which but $75,000 has been as yet laid out, they say, "that the bed of the road is graded 25 feet wide for a double set of tracks;" and that, "when completed, with the necessary machinery, it is at present estimated to cost $1,271,718 18," being about $35,325 per mile.

In the sixteenth report of the Board of Public Works, to the General Assembly of Virginia, Mr. Crozet, the principal engineer of that commonwealth, in his report to the board, expresses himself as follows:

"From their acknowledged superiority in a great many instances in England, railways have obtained warm advocates in this country, though the opinion seems most generally to prevail that they are not applicable here. Without attempting to judge of what is expedient in other States, I am of opinion that, at least in Virginia, railways could not be extensively introduced."

The engineer then proceeds to consider the expediency of a railroad, as a substitute for the navigation of James river; and concludes (p. 491) with the following remarks in relation to a railroad across the mountains:

"The making of a railway across the mountains has been also mentioned; but it would be attended with still greater practical difficulties.

"In the first place, the mountains are so rugged and broken, that the only practicable way to carry this plan into execution would be to follow the valley of some creek, which leads up to the top of the dividing ridge. But here all the difficulties presented in the valley of James river would be greatly multiplied. The graduation of the road must be almost every where among cliffs; its windings would be more numerous and considerable; the deep cut would be enormously expensive, and the stationary engines and inclined planes very frequent, &c. After having, at an immense expense, established the foundation of the railway, blocks of stone must be obtained, shaped, and transported into a complete wilderness, and put into their place. Then castings must be obtained from a foundry at the rate of at least one hundred and twelve dollars per ton, and transported an immense distance to this same wilderness, to form a railway perhaps one hundred miles in length, at the rate of nearly one hundred tons of iron per mile, exclusive of fixed steam engines and machinery.

"In England, where facilities of all sorts are concentrated; where there exists an extensive practical knowledge of these things, the nice adjustment of railways may not be thought an object capable of having a material influence on the expense; but, among the mountains of Virginia, far from foundries, rails would have to be procured of particular shapes to suit each of the numerous curves of the road, and counteract the centrifugal force of the wagons in the turns.

"What the expense of railways, made under circumstances so unfavorable, would be, I am not prepared to say; but certain it is, that it would be immense, and that the present state of things would not justify it."

In a letter of this engineer, dated the 6th of August, 1831, to Benjamin Wright, who was associated with him in an examination and report on the best mode of improving the channel of intercourse along the valley of James river, he says, "As regards the railroad plan, I have estimated it as about equal to the cost of (meaning, evidently, *in cost* to) a canal."

The associate engineer, with more precision, says, in his letter to the Governor of Virginia, of the 7th of April, 1831—

"I arrived in Richmond on the evening of the 23d July, in order to commence upon the execution of the duties as associate engineer.

"I was a little disappointed in not finding the chief engineer at the seat of Government: the fault is, perhaps, partly chargeable to myself, in not adverting to the fact of the great extent of territory of the State; and that the duties of the chief engineer might call him to the extreme parts of it, and, therefore, a longer notice of my intention to visit here ought to have been given.

"In waiting the return of the chief engineer, I have (through the kindness of the Second Auditor,) employed my time usefully and beneficially, in the examination of all the reports, plans, profiles, and estimates, &c., which have been made, from time to time, of the valley of James river and New river, and the intermediate country, where a probable connexion, as contemplated by the act of April 7, 1831, might be made.

"On the 3d of August, the chief engineer arrived in Richmond, and the next day we had a conference upon the proper course of duties to be pursued under the act of the State, and the appointment which brought me here.

"I took the liberty to address a note to him, a copy of which I enclose, as also his reply thereto.

"Your excellency will perceive, that the chief engineer has, by his former official reports, at various times, expressed opinions upon the kind of improvement adapted to the James river valley, which opinions I could not expect he would controvert. Situated as I now am, I have only to make up an opinion of my own, which I have done from the reports, estimates, plans, and profiles, before referred to, and from a personal examination of the valley of James river, from a point above the Blue Ridge, to Richmond, for an improvement of this kind, in 1824.

"By the act of the Legislature above named, it appears there are three plans or kinds of improvement to be *examined* and *estimated*;

"1st. Dams and locks—Moving power, supposed steam.

"2d. Canal—Continuous.

"3d. Railroad from Richmond to Lynchburg, and supposed to be continued westward to the proper point on the western waters.

"If the act contemplated an estimate of the whole of the several routes mentioned in it, from a personal survey made by us, all these duties could not be preformed in less than two or three years, in such manner as an engineer would like to be responsible for. Believing as I do, that any further survey to enable me to make up an opinion of the kind of improvement which the State ought to adopt, are unnecessary, and that an approximation of the cost of executing such improvement can be as nearly determined at this time, as is useful or important to permit a legislative body to act benefi-

cially for the State, I take the liberty to give that opinion, which you can use as you think proper.

1. Lock and Dam Navigation, with a moving power by steam tow-boats.

"I have careful examined the report and estimate of the chief engineer, for locks and dams in James river, from Maiden's Adventure to Covington.

"I am very sorry I cannot agree with him as to the cost of such a work. My own experience, and what I have seen of such works executed by others, applying the principles as far as they are applicable to the James river valley to Lynchburg, assure me that I cannot make such an improvement for double the money estimated.

"If such an improvement was made, there are strong objections to the moving power. It requires too much mechanical skill, and either the State or some wealthy individuals must become the carriers.

2. Railroad.

"If a railroad should be adopted, it ought to start from Richmond instead of Maiden's Adventure; this would destroy all the use of the present canal.

"I do not believe a railroad, with two tracks, permanently constructed, and proper turn-outs and fixtures, can be constructed for so small a sum per mile as a good canal.

"It requires great mechanical skill, if the moving power is locomotive engines, and, without these, applying only horse power, it will be found that no great speed is gained, and it is certain that the expenses of transportation per mile will be much greater than on a canal. Property cannot be as safe from storms and depredations as in a good canal boat under lock and key.

3. Continuous Canals.

"Of all the three plans which have been directed by the act, so far as the valley of James river from Maiden's Adventure to Lynchburg, the best, in my opinion, is an independent canal, with such connexions with the river as can make it accommodate the south side.

"The simplicity of a canal, and its adaptation to the capacity of every man in the community, will certainly make transportion on it cheaper than any other mode.

"It is, without doubt, better suited to James river as far as Lynchburg, and, probably, taking into consideration what has been done at the Blue Ridge, it ought to be extended beyond that point. Every man is his own carrier, if he chooses to be so: he moves as he pleases, and stops when he pleases, if he does not interrupt others, in a canal.

"The question arises, then, if a canal is to be made, what shall be the size of it?

"If the canal between Maiden's Adventure and Richmond can be so altered as to bring it to the size I would wish, (and I am inclined to the opinion that it can be so done, without very great expense,) I would then recommend that the canal from Maiden's Adventure to Lynchburg, should be fifty feet surface, thirty feet bottom, with five feet depth of water in all its parts, where the excavation and embankments were good. At the heavy bluff points of rocks, where it is expensive, I would reduce the width so as barely to permit two boats to pass each other. Where I had culverts of any considerable size, I would reduce the width to forty feet, so as to save ten

feet of masonry. The aqueducts I would build of stone, if good stone could be found, and cement is not too expensive. These I would have 19 or 20 feet water way.

"The present locks are built 85 feet between the gates, and 16 feet wide. These are entirely too wide for the canal. I should prefer locks of the length of the present ones, but not more than 14½ feet wide, or 15 feet at the extreme.

"Such a canal can be built along the valley of James river, from Venture falls to Lynchburg, *under good management*, for 18 to 20,000 dollars per mile, provided water cement can be procured at or near the Blue Ridge.

"It is proper that I should give a reason why I would enlarge the canal to the size I have mentioned, and give the banks a slope of 2 to 1. It is well known, by experience, that common earth is inclined to assume this shape when washed by water, and my experience leads me to believe, it is better to form the banks with this slope at first, than to supply the abrasion of the banks with new earth after they have washed down and assumed this shape.

"Such banks, when raised above the natural earth, are stronger; they will sooner take vegetation and be protected from wash; or, if abraded, they are easier protected by a few small stones thrown along next the water surface.

"Many persons who have not examined the question, suppose that a canal increases in cost according to size: this is not the fact. It will be found, that, for a canal of the size I have mentioned, the additional expense of excavation and embankment over a canal of the size of the New York canal, will not exceed from 6 to 8 per cent., and this item forms the whole additional expense: the locks, aqueducts, and culverts, being the same upon the plan I propose.

"On comparing a cross section, it will be found that the one is 200 feet, the other is only 136 feet; and a boat loaded and moving at the rate of 3 miles per hour, the power to move her will be nearly 20 per cent. less, in the large, than the smaller canal.

"Such a canal will permit boats 75 feet long, 14 feet wide, and drawing 4 feet water, to carry 70 to 75 tons, if desired. My own opinion is, that the most profitable kind of boat will be found to carry about 50 tons.

"I have been thus particular in my views of a great plan of improvement from Maiden's Adventure to Lynchburg, and probably the same ought to be continued above the Blue Ridge.

"From the point where a canal ought to stop, and a railroad commence, all the examinations are not quite complete: enough is known to show that there is a favorable place to pass the Alleghany, either with a railroad or canal. So far as I have examined the surveys made, the formidable difficulties appear to be on the New river: these may require examination to determine what kind of improvement ought to be adopted.

"The law of April 7, 1831, appears to require of the engineer to state the advantages and disadvantages, the commercial benefits, the probable revenue, &c.

"Any statement of this kind, from me, would not be entitled to a moment's consideration. It is well known to all persons who have been conversant with the opening of canals in this country, that a new kind of trade is opened: articles which could never reach a market, by reason of the great expense of transportation before the canal was opened, are brought in great abundance afterwards. It is well known, that more than half the tonnage

means of conveyance, (especially when their relative economy is the same,) unless they can be made to partake of the general activity, and additional celerity given to the boats conveyed upon them. Experiments, to ascertain the amount of resistance at different rates of speed, would be therefore highly valuable; and it is to be hoped that such will be made on a practical scale upon some of the canals, to show how far they are capable of affording a more speedy transit.

"The existing agitation of the public mind, respecting the relative utility of railroads and canals in the transit of goods from one place to another, renders it a subject of proper inquiry to ascertain the relative performances of the different kinds of motive power upon those two species of internal communication.

"I shall, therefore, give a brief comparison, founded on the foregoing deductions of the different kinds of motive power upon railroads, with the performance of horses by the present mode of canal navigation.

"Not having had an opportunity, from my own personal observations, of ascertaining, with sufficient accuracy, the weights which a horse will drag in a boat upon a canal, I shall be obliged to have recourse to the reports of those engineers whose practice in that line has enabled them to obtain the necessary data.

"Mr. R. Stevenson, of Edinburgh, in his report on the Edinburgh railway, in 1813, states, 'upon the canals of England, a boat of thirty tons' burden is generally tracked by one horse, and navigated by two men and a boy; on a level railway it may be concluded that a good horse, managed by a man or lad, will work with eight tons; at this rate, the work performed on a railway by one man and a horse is more than in proportion of one-third of the work done upon the canal by three persons and a horse;' and Mr. Stevenson, in his calculations afterwards, assumes the power of a horse, upon a good railway, equal to ten tons.

"Mr. Sylvester, in his report on the Liverpool and Manchester railway gives twenty tons as the performance of a horse upon a canal, travelling at the rate of two miles an hour.

"The variation between the two statements may have arisen from the observations being made on canals of different widths. Mr. Stevenson, in another report, states, that the striking difference between the draught of horses on coming out of a narrow canal into a more capacious one, induced the reporter to give the subject particular attention; and, by means of experiments made with the dynamometer, so far as he had an opportunity of carrying the experiments into effect, the difference appeared to be at least one-fifth in favor of the great canal.

"Under these circumstances, I shall take the performance of a horse equal to that of thirty tons upon a canal, which is the greatest I have seen assigned by any one, and we have previously found the energy of his power equal to ten tons upon a railway: which will make the relative performances as 3 : 1.

"I am not acquainted with any experiments, made on a practical scale, to ascertain the ratio of the increase of resistance, either with different weights, or with the same load moved at different velocities, upon a canal; but it is assumed by all writers on the subject, as a law of hydrodynamics, which appears unquestionable, that the resistance at least is proportionate to the square of the velocity.

"Taking these premises as sufficiently established, the diagram III* will represent the resistances at different velocities; and the following table will show the relative quantity of work performed by horses dragging boats on canals, and carriages upon railroads.

Velocity in miles per hour.	Weight conveyed in cwts.	Distance in miles, being that which a horse travels in a day.	Resistance upon a canal in lbs., taking a horse's power at 112 lbs., and supposing this force will drag a boat of 30 tons at two miles an hour.	Resistance upon a railroad in lbs., as per Table VIII.	Power which a horse can exert upon the load, at the respective velocities, from formula $\frac{224}{v}$	Number of horses required to perform the work upon a canal.	Number of horses required to perform the work upon a railway.	Ratio of the performance of horses, with respect to work on canals and railroads.
2	800	20	150	448	112	1.3	4	4: 1.3
3	800	20	337	448	$74\frac{2}{3}$	4.5	6	6: 4.5
4	800	20	600	448	56	10.7	8	18:10.7
5	800	20	937	448	$44\frac{2}{5}$	21.2	10	10:21.2
6	800	20	1,350	448	$37\frac{1}{3}$	36.	12	12:36.

"From this we find, that, when the rate of speed is about two miles an hour the quantity of goods which a horse will convey upon a canal is three times that which the same horse can convey upon a railroad; and that when the velocity on each is about $3\frac{1}{2}$ miles an hour, the resistance of the canal increasing as the square of the velocity, while that on a railroad remains the same, the two become equal; and a horse is then enabled to drag as much weight upon a carriage on a railroad, as in a boat on a canal. When the velocity is further augmented, then the disproportion becomes greater, and a much heavier load can be conveyed on a railroad, with the same intensity of motive power, than can be done on a canal.

"If, therefore, the rate of tonnage on a canal, arising from the cost of forming and keeping it in a state of active use, together with the cost of boats, be not greater than the tonnage required to form and keep a railroad in repair, and also the carriages by which the goods are conveyed; then the relative economy at different rates of speed, in the transit of goods upon canals and railroads, will be represented by column nine of the preceding

*III.

Velocities - - - -	1	2	3	4
Spaces - - - -	1	1	1	1
Times - - - -	1	1	1	1
Resistance - - - -	1	4	9	16
Mechanical force required, acting for the above time } - -	1	8	27	64
Mechanical force required, for any given distance } - -	1	4	9	16

now passing on the Erie canal, consists of property which would never have been moved at all, but for this easy and cheap conveyance.

"This view of the question makes it impossible for any one to do more than conjecture the result of a great work of this kind.

"If it was thought proper, in constructing, a canal to make locks, aqueducts, &c., of more temporary materials, the costs per mile would be reduced, probably, 20 to 30 per cent., but I cannot recommend this plan for such a work, in such a place as the valley of James river, and for the State of Virginia."

In a subsequent letter from the same to the same, dated August 9, 1831, he says:

"I have drawn up a short report, in which I have given opinions as to the various plans of improvement adapted to the valley of James river, and decided upon what I think best.

"I have not gone into long arguments to show why a canal is better adapted to the peculiar location of this valley. The simple fact that it is that kind of machine which, in its use, is brought to the capacity and understanding of every man in the community, is, in my mind, enough to decide the question.

"As to the cost, I have fixed the maximum, *under good management*, and this will make a permanent, excellent work. If the Legislature choose to make a less permanent work, of course, the cost of it will be considerably less.

"I have not touched upon, or made any remarks, as to the improvement from a point on James river, to New river. A railroad will, no doubt, be the improvement which ought to be adopted, and the surveys now going on will determine the best route, probably.

"The public mind is now so unsettled in their opinions on the comparative advantages and disadvantages between railroads and canals, and considering that it will take some little time to have the good people of Virginia satisfied, I have had doubts in my mind whether it would be useful for me to return here again. I fear I can do but little, if any good, under the impressions I now view the matter, and I presume you will see it in the same light. I have explained myself fully to Captain Crozet and to the Second Auditor.

"I can only say that, if I can render good service to Virginia, I would return in October, but my view of the whole ground is against it, under a full belief that it would be useless. I regret that I could not have the pleasure to see you. The situation of my private affairs, which I adverted to in my former letter, make it very important for me to return to the north at this time."

In two reports made to the Liverpool and Manchester Railroad Company, by two eminent civil engineers, who were empowered, prior to making their reports, to visit all the railroads in use in England, for the collection of suitable materials to solve the inquiry propounded to them by the officers of that company, which was, by what means of transportation their railroad could be most effectually made to subserve its ends, the public convenience, and the profit of the stockholders? it is distinctly stated to be their opinion, that the commerce and intercourse between Liverpool and Manchester are not competent to maintain the cost of the application of *stationary* steam engines to that great thoroughfare; and that a greater velocity, than of ten

miles an hour, ought not to be attempted by the *locomotive* engines, which they recommend as a less expensive propelling power than the stationary. It was designed to incorporate, in this note, copious extracts from the reports of those engineers, which have, however, been mislaid.

From an English work on railroads, of prior date, and by far the most valuable now extant, that of Wood, the following extracts will show that, in 1825, the date of the publication of his treatise, the question was not regarded to be settled as to the relative value of railroads and canals. "Canals," says this writer, "ever since their adoption, have undergone little or no change; some trivial improvements may have been effected in the manner of passing boats from one level to another, but, in their general economy, they may have been said to remain stationary. Their nature almost prohibits the application of mechanical power to advantage in the conveyance of goods upon them; and they have not, therefore, partaken of the benefits which other arts have derived from mechanical science.

"The reverse of this is the case with railroads; their nature admits of the almost unrestricted application of mechanical power upon them, and their utility has been correspondingly increased. No wonder, then, that canals, which, at one time, were unquestionably superior to railroads in general economy, by remaining in a state of quiescence, should, at some period or other, be surpassed by the latter, which has been daily and progressively improving; and perhaps that time is arrived. The human mind is generally averse and slow in adapting itself to the changes of circumstances; and though from this cause the competition in consequence might not have been so speedily brought into action, had not the present prosperity of the country induced capitalists to seek out every source of speculation, affording the least prospect of success. The natural course of events would, however, soon have developed the real situation of the two modes, in their respective relations to each other; and though the time might have been prolonged when railways were brought into active competition with canals, yet its arrival would not be the less certain.

"One might be led to suppose, that the question could readily be solved by an appeal to facts, or by the comparison of particular canals with similar railways; but it is here, I presume, where the difficulty lies; we cannot perhaps find canals and railways whose external features are precisely the same: we are obliged, therefore, to have recourse to a comparison of general facts or principles peculiar to each mode, which, again, cannot be accomplished, unless we are fully and intimately acquainted with all the various properties and characteristics of each mode. The want of proper data was felt, and it is with a view of furnishing these, that the present work was undertaken; which, by a concise, and at the same time comprehensive description of the construction, uses and advantages of railroads, together with an elucidation of the various principles of their action, the reader might be enabled to make a comparison with other modes of internal communication, and thus form a judgment of their relative value.

"It is much to be regretted that a similar inquiry has not been made with respect to canals; the present state of commerce requires that goods should be conveyed from place to place with the utmost rapidity, and perhaps we owe no small portion of mercantile prosperity to our facility of despatch. The slow, tardy, and uninterrupted transit by canal navigation must, therefore, of necessity yield to other modes affording a more rapid

tons, the whole mass moved is about thirty-three tons; and the average force of traction he found to be eighty pounds." (Id. p. 150.)

TABLE V.

A TABLE showing the effects of a power or force of traction of one hundred pounds, at different velocities, on canals, railroads, and turnpike roads.

Velocity of motion.		LOAD MOVED BY A POWER OF 100 LBS.					
		On a canal.		On a level railway.		On a level turnpike road.	
Miles per hour.	Feet per second.	Total mas moved.	Useful effect.	Total mass moved.	Useful effect.	Total mass moved.	Useful effect.
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2½	3.66	55,500	39,400	14,400	10,800	1,800	1,350
3	4.40	38,542	27,361	14,400	10,800	1,800	1,350
3½	5.13	28,316	20,100	14,400	10,800	1,800	1,350
4	5.86	21,680	15,390	14,400	10,800	1,800	1,350
5	7.33	13,875	9,850	14,400	10,800	1,800	1,350
6	8.80	9,635	6,840	14,400	10,800	1,800	1,350
7	10.26	7,080	5,026	14,400	10,800	1,800	1,350
8	11.73	5,420	3,848	14,400	10,800	1,800	1,350
9	13.20	4,282	3,040	14,400	10,800	1,800	1,350
10	14.66	3,468	2,462	14,400	10,800	1,800	1,350
13.5	19.9	1,900	1,350	14,400	10,800	1,800	1,350

"TABLE V.—This table is to show the work that may be performed by the same mechanical power, at different velocities, on canal, railroad, and turnpike roads. Ascending and descending by locks on canals may be considered equivalent to the ascent and descent of inclinations on railroads and turnpike roads. The load carried, added to the weight of the vessel or carriage which contains it, forms the total mass moved; and the useful effect is the load. To find the effect on canals at different velocities, the effect of the given power at one velocity being known, it will be as $3^2 : 2.5^2 :: 55,500 : 38,542$. The mass moved being very nearly inversely as the square of the velocity.

"This table shows, that when the velocity is five miles per hour, it requires less power to obtain the same effect on a railway than on a canal; and we have added the lower range of figures to show the velocity at which the effect on a canal is only equal to that on a turnpike road. By comparing the power and tonnage of steam vessels, it will be found that the rate of decrease of power by increase of velocity, is not very distant from the truth; but we know that in a narrow canal the resistance increases in a more rapid ratio than as the square of the velocity, only we have not time to spare to follow up the inquiry at this moment. Other tables of a similar

kind have been published, and we find our column exhibiting the useful effect on canals nearly agrees with that of Mr. M., the ingenious author of a series of essays on the subject, which first appeared in the Scotsman; but we differ respecting railways, his being more in favor of railroads. From Mr. Sylvester's table this differs very considerably: he has underrated the effect on canals as much as he has overrated the effect on railways and common roads."

It is proper to remark, that, from Tredgold, as from other English treatises on railroads, passages may be extracted, less favorable, than the preceding, to the superiority of canals: but enough is here quoted to show the uncertainty which hung over the question, whether canals or railroads were to be preferred for the transportation of persons and property. No two authors, scarcely, will be found to concur precisely in opinion on the subject, nor the same author with himself.

The knowledge possessed by the founders of the Baltimore and Ohio railway of the superiority of railroads to canals, was comprised in the pamphlet detailing their proceedings, from which copious extracts have already made part of note N.

It is there introduced in the following language of the report of their committee, beginning on the 7th page of the proceedings:

"The stock of information upon the general subject of railroads, now in the possession of the committee, is admitted not to be very extensive, but they have gleaned from the several publications and reports which they have examined upon this interesting subject, enough to leave no doubt upon their minds that these roads are far better adapted to our situation and circumstances than a canal across the mountains would be: they therefore recommend that measures be taken to construct a double railroad between the city of Baltimore and some suitable point on the Ohio river, by the most eligible and direct route, and that a charter to incorporate a company to execute this work be obtained as early as possible; and, in support of this opinion, they submit the following views and statements."

Among these statements, which are all from books and pamphlets in common circulation, are the following:

"The proprietors of the *few* canals which do answer, will have the greatest reason to complain," (that is, of the introduction of railroads;) "but they must, of course, submit to any superior method of improving the conveyance or transport of merchandise, just as the common coasting traders will to the established steam vessels: with respect to those canals which do not answer, and those that never can, the sooner they are abolished, in toto, the better." (Gray, p. 66.)

"The expense of forming railways is not only, *far less*, than that of canals, but the former exhibit the peculiar advantage of a better conveyance than roads and canals conjointly afford at present. (Gray, p. 67.)

"The mode of conveyance that most nearly assimilates to railways is canals; but to them, *the agency of steam cannot be available*, as they are *limited to the size of their loads*, and, as regards utility, to the speed of conveyance; for, to draw a load of forty or fifty tons, with double the speed that is now done, by one horse, could not be effected, on a *common canal*, by any power that can be applied." (Jessop in Gray, p. 103.)

"A railway can, according to circumstances, be made at from *a half* to a *fourth of the expense of a canal*, and convey goods more cheaply, which

able. But as, in general, the formation of a canal costs about *three times as much* as the formation of a railway, and the annual charges of keeping the boats, towing paths, and bridges, &c. in repair, is also considerable, if those expenses be as much greater with a canal than upon a railroad, so that they will compensate for the extra advantage of the canal in the greater quantity of goods conveyed at a slow rate, then their relative utility will assume a different appearance, and the railway, as requiring a less investment of capital, and less annual charges, may be superior, even at the lowest and most advantageous rate of motion, upon canals; and, where facility or expedition is an object, then, at the more rapid rates of speed, the railway will be proportionably superior.

"These, however, being matters of calculation, where every instance may present a different conclusion, and depending upon all the various concomitant circumstances incident to each particular case, cannot, in a work like this, be made the subject of *even conjecture.* I have endeavored to furnish all those data which appeared general, and which applied to the two modes in conjunction with each other, in a practical and general point of view. It must be left to those acquainted with all the circumstances of each particular case, when they come into competition with each other, to judge, *from the individual situations, which of the two is preferable.*

"When it becomes a subject of discussion, which of the two modes are to be adopted, it assumes rather a different shape, than when a railroad is to enter into competition with a canal already formed. *In the latter case, the canal proprietor commences with considerable advantage by the additional quantity of goods which a horse can drag at a slow pace upon a canal, where perhaps a little loss of time may be no object;* the canal proprietor may, *even with his great investment of capital, by reducing his rates of tonnage extremely low, be enabled to compete successfully with a railway.*

"For, although a horse may, when travelling at the rate of four or six miles an hour, convey a greater quantity of goods upon a railway than when employed in dragging goods at the same velocity upon a canal, yet still a horse cannot drag more goods at the rate of four miles an hour upon a railway, than he can at two miles an hour upon a canal; for, in no case, does the greatest quantity of work that a horse can do, at the most beneficial pace on a canal, *reach below three times that* which a horse can do at any pace upon a railroad.

"For the conveyance of passengers, or where the transit of any species of goods may require a celerity of four miles an hour, then railways become unquestionably more economical than canals; but *if the question be the abstract performance*, or *quantity of goods to be transported* from one place to another, *without reference to speed,* then *the canals will at all times have a superiority over railroads,* in point of *quantity of work* done by a horse, in the proportion of 3 : 1. The comparative expense arising from the extra interest of capital, and the annual charges and maintenance of a canal, may reduce this proportionate performance near to an equality; or, if the one compensate for the other, then perhaps the less investment of capital in a railroad, and the greater certainty of transit, may make it superior to a canal; but unless the disparity of cost is great between a railroad entering into competition with an existing canal, or unless some extraordinary circumstances in the nature of the trafic occur, it may be difficult to

say, when horses are the motive power on each, which is superior." (Wood on Railroads.)

The writer in England on the subject of railroads, next in celebrity to Wood, is Tredgold, a member of the Institution of Civil Engineers, whose treatise was republished in New York in 1825.

"In discussing," he says, "the merits of railroads, we have to compare them with turnpike roads and with canals. Railroads give the certainty of the turnpike road, with a saving of seven-eighths of the power; one horse on a railroad producing as much effect as eight horses on a turnpike road. In the effect produced by a given power, the railroad is *about a mean* between the turnpike road and a canal, when the rate is about three miles an hour; but where greater speed of conveyance is desirable, the railroad equals the canal in effect, and even surpasses it." (Page 3, of the New York edition.)

"When it is attempted to compare railroads with canals or common roads, it must be obvious that each mode has its peculiarities: the same may be said of each line of traffic." (Id. page 8.)

"Both the first cost and the annual repairs of a canal exceed those of a railway; the excess differing according to the nature of the country. But in a country suited for a canal, the difference of first expense *is more than compensated by a greater effect produced by a given power on a canal than on a railway, provided the motion does not differ much from three miles an hour, and this renders a canal decidedly better for a level district.* On account of the resistance increasing in the ratio of the squares of the velocities, when bodies move in fluids, and also *on account of the injury the banks* would suffer by too rapid a movement of the water, the velocity of canal boats must be considered as limited to a speed not far exceeding that which they obtain at present; but, on a railway, a greater velocity may be obtained with less exertion, even where animal power is employed." (Id. page 9.)

"The average cost of a proper railroad, with a double set of tracts, will not be less than £5,000 sterling (or 22,222 dollars) per mile, when all the expenses in our list are included, and the works are done in a good and substantial manner." (Id. p. 141.)

The Liverpool and Manchester railroad, thirty-two miles long, is known certainly to have cost *three times* that sum, and rumor makes it nearer six times.

"From a list of estimates for no fewer than seventy-five canals, including those of the greatest and least expense, a writer in the Quarterly Review, No. 62, p. 363, draws a general average of £7,946 (35,280 dollars) per mile; but it is well known that these works have rarely, if ever, been executed for the estimated expense." "The Union canal cost £12,000 (52,280 dollars) per mile: the Forth and Clyde, £12,400" (54,056 dollars.) (Id. p. 143.)

"The average cost of a canal may be estimated at £10,000 per mile," (44,444 dollars.) (Id. p. 143.)

"Smeaton informs us that twenty-two tons burden, at from two to two and a quarter miles per hour, is the work of a horse on a canal. And Mr. Beavan has informed us that the horses on the Grand Junction canal usually travel twenty-six miles per day, and draw a boat containing twenty-four tons at the rate of 2.45 miles per hour; the empty boat being nearly nine

The appendix of the work, from which the above quotations are made, speaking of *another canal*, that between Birmingham and Liverpool, avers, as an argument for breaking down, or dividing, by means of a railroad, *its* long uncontested monopoly, that the original shares had risen from £140 sterling, to the sum of £2,840; and adds: "These facts on the increased value of this canal, which exceeds twenty times its original cost, prove, also, that the public transits might have been performed at much cheaper rates, and yet the company obtain an adequate remuneration."

The tolls on the Chesapeake and Ohio canal are not only limited to two cents per ton per mile, but the profit on any possible amount of tonnage, *to 15 per cent. on the capital expended.* The freight for carriage, left by law to be reduced by open competition on the public highway which the canal affords to every boatman who may please to use it, the experience of the Lehigh navigation, demonstrates, on a smaller canal, will not exceed one cent per ton per mile.

The Baltimore and Ohio Railroad Company, on the other hand, are allowed to charge for toll and transportation, from west to east, four cents per ton per mile, from east to west six cents; and their charter allows them to be the exclusive carriers, with no other limitation to the extent of their future profit.

The exclusive advocates of railways insist that the resistance of water to the motion of a canal boat increases, at every addition to its speed, in the ratio of the square of its velocity. Be it so. A single horse can draw, in a boat, on a canal, at the rate of two miles an hour, (the appendix to Gray affirms, page 206,) 90,000 pounds; consequently, at four miles an hour, he could draw but the one-fourth of that weight, or 25,000 pounds; but at one mile an hour, he could draw 360,000 pounds; and at half a mile an hour, the enormous weight of 1,440,000 pounds. Thus a single horse draws, on the large canal between Amsterdam and the Helder, a ship of several hundred tons. On the Champlain canal, a gentleman met a raft of timber so united, by a single plank, with a pivot for each lockhold of the long raft, that one horse drew it, with facility, at the rate of a mile an hour. It was from the lake, and then on its way to Albany; its computed weight was 200 tons, and the horse had drawn it the entire length of the Champlain canal. What velocity, and how many railroad cars would be required to balance the economy of this transportation? Yet a full moiety of the revenue of the New York canals is derived from the productions of the forest, in their rudest form. Would any contemplated speed of a carriage on a railway, which, at most, could but save the interest of a few days or hours on the very small capital vested in this vast moving mass of wood, countervail the cheapness of this slow voyage?

One great advantage attending the canal on which it was drawn is, that the swiftest packet boat, in meeting or overtaking such a raft, can pass it by, without the least obstruction, or a moment's delay. On a canal 60 feet wide, the tracks are never impeded by heavy carriages.

The numerous English authorities in favor of the superiority of railroads, in a country where there are, as yet, very few railroads, and there have long been more than one hundred canals, are contradicted, as we have seen, by American engineers, of at least equal merit, who, considering the very wide field which the United States present for both species of improvement, cannot be suspected of undue partiality for either.

But the disproof of the arbitrary and most extraordinary assertion of these

British writers, that canals are attended, in their construction, with *three*, and even *four times* the cost of railways, does not rest on mere authority.

The actual experience of both countries has now settled this question, provided the cost of the only railroad in England, adapted to an active exchange of commodities, or exceeding a few miles in length, be assumed, as the measure of the expense of such structures on that side of the Atlantic.

On turning to the numerous facts, developed by the past experience of both Europe and America, an impartial engineer will infer, amidst their seeming contradictions, some principles calculated to guide his judgment to a sound conclusion, as to the *original* cost, the *annual repairs*, and *expense of carriage*, of these two rival modes of internal improvement. Let these principles be then applied, so as to determine the relative cost of a canal and railroad, over every description of ground.

The most favorable ground, for any railroad, would, obviously, be that which required no graduation or masonry; or which, in its natural state, was ready to receive the rails.

Supposing a double track of these to cost no more, when laid on stone sills, than the first thirteen miles of the Baltimore and Ohio railway, which led to excellent granite quarries, it is obvious, that the cost of such a road, over such ground, would be at least $13,000, or, if the rails be laid on wood, not less than $10,000 per mile.*

Assuming a surface of country, alike favorable for a canal, we have to look, for the elements of a just calculation of its cost, to its plan and dimensions.

A canal of the dimensions and plan of the Erie canal of New York, of the canals of Ohio, and of the canals, in general, of Pennsylvania, having a breadth, at the surface, of 40 feet, at bottom of 28 feet, and four feet depth of water, with a tow path 9 feet, and a berm bank 5 feet wide, will require an excavation, in level ground, of $2\frac{94}{100}$ feet cutting, in order to supply the necessary quantity of earth for its embankments.

The cross section of the excavated prism of such a canal being $95\frac{28}{100}$ square feet, the number of cubic yards of earth to be excavated in one mile of it, would be $95\frac{28}{100} \times 5280$, the number of feet in a mile, divided by 27, the number of cubic feet in a cubic yard, or $18.632\frac{53}{100}$ cubic yards.

If this canal be required to be enlarged to the dimensions recommended for the Chesapeake and Ohio canal by the United States' Board of Internal Improvement, in their report of October, 1826, that is, to 48 feet at the surface, 33 feet at bottom, with 5 feet depth of water, and embankments of the height or breadth of the former, its depth of cutting, in the same ground, will be the same as in the last case, or $2\frac{94}{100}$ feet. The prism of earth to be excavated to form its embankments will have a cross section of 110 square feet, and will contain $20,770\frac{37}{100}$ yards.

If this canal be extended to the size of that, 48 miles of which are already constructed in the valley of the Potomac, between Washington and the "Point of Rocks," that is, to a breadth, at the water line, of 60 feet, at bottom of 42 feet, with a towing path 12 feet, and a berm bank 8 feet broad at top, elevated two feet above the water, and having moderate slopes towards the bottom, then the necessary depth of cutting will be $3\frac{24}{100}$ feet, the cross section of the excavated prism will be 157 feet, and the number of cubic yards to be excavated, $30,700\frac{22}{100}$.

*In a late estimate for the extension of this road to the District of Columbia, the cost of a double track of rails is computed at 15,000 dollars a mile, and of the entire road near 50,000 dollars a mile, for the distance of 29 miles, between the present railroad and the District line. (See ante.)

would render them lucrative when any other mode would be ruinous." (Idem in Gray, p, 104.)

"Railways may be constructed at *one-fifth of the expense of canals;* and, as it has been shown that they will convey as cheaply, where the prospect of remuneration to the adventurer in one case is doubtful, the *lesser expense* makes the other *certain.*" (Gray.)

Whether these essayists merited all the confidence reposed in them, experience has already determined, in the relative cost of a considerable part of that very canal, denounced as affording *too tardy, circuitous,* and *expensive* a route to the Ohio, compared with the *actual cost* of a correspondent part of a railroad from Baltimore towards the "Point of Rocks,"—a canal exceeding greatly, in dimensions, as well as in the difficulty of its construction, any canal in England, and surpassed in breadth by but one in Great Britain, compared with a railroad of two tracks only.

At the moment of the publication of this pamphlet, it had been ascertained that the railroad between Manchester and Liverpool, of two tracks, in length not thirty-two miles, and surmounting an elevation of less than 150 feet, would exceed in cost sixty thousand dollars a mile! Its actual cost has surpassed, it is currently believed, the double of that sum.

That the cost of the Ohio canals has not exceeded 11,000 dollars per mile has already been noticed, as well as the computed cost of the Erie canal of New York, which has, in fact, been less than 18,000 dollars the mile; its price was made to reach 23,000 dollars, by the addition of interest on loans, which have no relation to the contract prices of the works of a canal, and depend, for their necessity and their terms, on the wealth or credit of the borrower.

The conclusion that permanent railroads, of several tracks, cannot be constructed at one-fifth of the expense of canals, may be farther confirmed by reference to the cost of the canals of Pennsylvania, New Jersey, and Connecticut. The eastern section of the Chesapeake and Ohio canal is expected to cost from 25 to 30,000 dollars the mile; but a canal of such dimensions should be compared with no railway of less than four tracks; and the rails, alone, of such a road, would probably cost more than that sum, exclusive of the graduation of the road.

The greater part of the extracts from treatises on railroads, made by the Baltimore committee, (in 1827,) were, as we have seen, from a work entitled "Gray's Observations on a General Iron Railway," the fifth edition of which was published in 1825.

The following extracts from the very same work, show the importance of having presented both sides of the question now made, between the advantages of canals and railroads.

"In order," says Gray, in examining the same authority, "to establish a general iron railway, it will be necessary to lay down *two* or *three* railways for the *ascending, and an equal number for the descending vehicles.*" (Page 12.)

"In the immediate neighborhood of London, the traffic might demand six railways." (Page 12.)

"It is desirable to show the probable expense of this scheme, but this depends almost entirely upon the state of the country through which it may be found necessary to pass."

"Wagons laden with merchandise can never expect to proceed with the same velocity as coaches." (Page 12, 13.)

"By the second extract it will be seen, that the sums quoted, as the expense of railways, vary too much to be depended on." (Page 13.)

"Mechanic power, when once put to the test, by comparison on land and water, will, *no doubt*, prove more favorable on the former, in proportion as that element is *more stable*, and not under the influence of *winds, tides, or currents.*" (Gray's Observations, &c.)

And from the appendix to the above edition of this work, the following passages merit attention: "On the whole, then, it may be concluded that, on a level team-road, making allowance for the weight of the wagon, one horse will be required for every four tons of coal, or other articles conveyed; and, on an edge railway, one horse will be required for every seven tons. On an ordinary canal, one horse, with a boat, will be sufficient for eighty tons. But the first cost of a canal is *three* or *four times* greater, than that of a railway; so that, in some cases, *it may become a question*, whether a railway might not be adopted with advantage." Page 178.

"The public in general entertain wrong impressions respecting railways; they never hear them mentioned, without recurring to such as are seen in the neighborhood of coal pits and stone quarries. But such improvements have taken place, that they are no longer the same thing; besides which, a railway, *without a locomotive engine*, is something *like a cart without a horse, a trade* without profit, or a *canal without water.*" (Page 184 and 185.)

"On a canal, a horse, travelling at two miles an hour, draws 30 tons, in a boat weighing probably 15 tons. Reducing the ton to 2,000 pounds, for the sake of round numbers, as in the last calculation, we find here that a power of traction of 100 pounds moves a mass of 90,000 pounds, or the resistance which the water opposes to the motion of the vessel is equal to one nine-hundredth part of the load or entire weight. At sea, where the water is of unlimited breadth, the resistance probably is one-third less."

"We see, then, that the effect produced by the draught of a single horse is ten times as great upon a railway, and thirty times as great upon a canal, as upon a well made road; yet a railway costs only about *three times* as much as a good turnpike road, and a canal about *nine* or *ten times* as much."

"With regard to the comparative advantages of canals and railways, *so far as the present facts go*, we may observe, that, if a horse power effects three times as much upon a canal as upon a railway, the canal costs about *three times as much*, and will of course require nearly the same rates or dues per ton to make the capital yield the same interest." (Pages 206 and 207.)

"Railroads, as hitherto worked by horses, *possess very little*, if any, *advantage over canals;* but railroads worked by the locomotive steam engine, have so decided a superiority, both as it regards time and expense, that there can be no question but they will be generally adopted wherever a new line of conveyance has become necessary, either *from an increased trade*, or from the *exorbitant demands of canal proprietors.*" (Page 185.)

Here is the true secret of the imputed superiority of railroads to canals in England: the former are designed to break down a very lucrative monopoly, which had, in some cases, when this author wrote, swelled the profit of certain canals so high, that, on that of the Trent and Mersey, as he informs his readers, £75 was the annual dividend on a single share of £100 original cost, which was selling in December, 1824, at £2,300 advance on the £100; yet this canal has three tunnels, one of 2,880 yards, and another of 1,241, in 22 miles, and two aqueducts, of which, that over the river Dove has 23 arches.

is not to be assumed as a standard to measure the relative cost of all railroads and canals. The canals of New York cost about 18,000 dollars a mile, those of Ohio have cost very little more than 11,000. The Farmington canal, in Connecticut, cost less than either. The canals of Pennsylvania will cost less, per mile, than her railroads. The disparity would have been greater, but for moral or *political* rather than physical causes.

To proceed with the second object of inquiry, *the cost of transportation* on railroads and canals.

The amount of tolls and the cost of transportation on the Baltimore road and the Potomac canal, are regulated, to a certain extent, by the provisions of their respective charters. The railroad being a close monopoly, and not a public highway like the canal, the transportation, as well as the tolls upon it, is left with the company, which is required not to exceed 4 cents per ton per mile, in its charge on the tonnage moving eastwardly; nor more than 6 cents on that moving westwardly. The canal tolls are limited, in both directions, to 2 cents only per ton per mile; and the charge for transportation on the canal, if its trade be active, in both directions, will probably be reduced, by competition, to one-third of a cent a ton. Under no circumstances, will it exceed one cent a ton per mile. So that, by the permission of their charters, the Railroad Company may charge 33 1-3 per cent. more for toll and transportation, one way, and 100 per cent. more the other way, than the Canal Company. If, however, departing from the limitations of their charters, these two companies were allowed equal nett profits, then the relative magnitude of the burthens which they would impose on the people, supposing that profit to be equal, and their tonnage too, would depend, as stated in a former note on the relative cost of their works, their relative repairs, and their rate of transportation. If the relative cost of the construction of the canal and road be the same, then, on their respective annual repairs and rate of transportation. Now, the lock gates are almost the only perishable parts of a canal constructed of such materials, as compose that now passing up the valley of the Potomac. Its very wide and solid embankments of earth, often paved with stone, its massy walls, its locks, culverts, and aqueducts of durable freestone or granite, united by hydraulic cement, will be strengthened, rather than impaired, by time. While every part of a railway exposed to the action of the weather, to the constant attrition of heavy cars, and heavier locomotive engines, moving with great velocity, and alike injurious to the road and its carriages, to say nothing of its wooden sills, for two-thirds of its route, or of its aqueduct of wood across a considerable river, is liable to gradual, though certain wear, and to ultimate destruction or continual repairs, from the very use which constitutes its profit.

Although the late report of the President and Directors of the Baltimore and Ohio Railroad Company forbears to include the repairs of any part of their road, or of their cars, among the expenses, involved in the collection of the tolls of nine months receipts, the suggestion, in the report of their chief engineer, that "the durability of the road," to use his own language, "and of the cars, and especially of the wheels, would be promoted by the use of springs;" and again, that "the concussions upon the rails are very considerable, and are greatly augmented by an increase of the rapidity of the movement," would indicate that *some expenses*, from these causes, had been already incurred, and should be considered as involved in the receipts.

To diminish such expenses, the Liverpool and Manchester Railroad Com-

pany are said, to employ several hands with brooms and scrapers, for every mile of their road, to cleanse it of dust; an expense, which the cheaper labor of England may possibly enable their road to bear; but which would, of itself, much detract from the profit of any railroad, even amidst the most crowded population of America; to say nothing of the solitudes of the Alleghany and its parallel ridges.

Some of the British authorities in favor of the superior economy of railroads, were invoked to their aid, by the Baltimore and Ohio Railroad Company in their early appeals to the public, and have been more recently quoted, with approbation, by their chief engineer; but they do not appear to have been sustained by the progress of that enterprise, either as regards the *comparative cost* of the road itself, or the *comparative cheapness of its transportation*.

Of the last, we have not been allowed to judge at all; since *two essential ingredients* of any just estimate, are singularly omitted from the late annual report of the President and Directors, viz. *the cost and repairs* of the necessary carriages; and *the wear and tear*, or repairs, of the road itself.

If the *acknowledged* expenses of transportation bear the same proportion, to those which are *omitted*, that the experience of other railroads in America warrant the belief, then, it is more than probable, that a just comparison of the receipts and disbursements of this company, for nine months of the present year, would bring them in debt; since "the moving power, drivers, and engine men, agents and conductors, depot expenses, oil, and" certain "contingencies," &c., (amounting to 482 dollars,) required an outlay of very near 11,000, out of the gross receipts of 31,405 dollars, being, as the Superintendent says, "of 1 to 2.86." Computing the 81,905 passengers on this road, who were attracted to it, mostly, as Mr. Woodville, the Superintendent, states, "by novelty or amusement," at the allowance of 12 persons to a ton, and the entire tonnage of the nine months use of this road, between Baltimore and Ellicott's Mills, or for 13 miles, is about 12,750 tons.* Of this, the greater part of the passengers, amounting to 6,825 tons, travelled out and in, or about 26 miles; the commodities, 5,931 tons, it is presumed, in no instance, more than half that distance, or 13 miles. The whole operation, therefore, is equivalent to the carriage of 254,553 tons a single mile; and the charge of $10,994 87 cents, for the moving power exerted in 9 months, on this railroad, is more than 4⅓ cents a ton per mile, totally excluding any allowance *for profit*, or *interest* on the first cost of the road or of its carriages, the *repairs* of those carriages, or the *necessary repairs* of the road in use.

Against this estimate, it might be said, with truth, that the transportation of persons requires a greater number of carriages than the transportation of commodities of equal weight, since these may be packed in a less compass.

* The Superintendent makes the total tonnage, no doubt, more correctly, "amount to upwards of 1,100 tons per month;" which, allowing for the indefinite form of expression, could not be supposed to swell the aggregate for the nine months much, if any thing, beyond 10,000 tons. If so, the calculation here made is more favorable to the economy of this road than it should be, by more than 25 per cent., so far as the expense of the moving power is involved in it. He also expressly says, that, under the head of expenses of "transportation, he does not include any charges for the construction, the repairs, or the wear and tear of wagons and cars; that branch of the service being under the immediate care and superintendence of a committee of the board," who, it appears, have excluded any notice of it from the text of the report, and have not thought proper to say any thing about it in its voluminous appendix, making, together a work of more than 130 pages.

The price of the excavation will depend on the quality of the earth. But that being supposed in this case to be such, as is ordinarily encountered, where neither hard pan, slate, nor rock is in the way, $9\frac{9}{10}$ cents per cubic yard may be taken for the measure of its excavation, that being found to be the average rate of such excavation, throughout the entire Chesapeake and Ohio canal, for a distance of 48 miles. So that, if these three canals be charged with the same price, per cubic yard, for their excavation, the narrow and shallow, as the wide and deep, which, for the first and second would be a very unfavorable estimate, then the canal, 40 feet wide and 4 feet deep, would be completed for $1,845 the mile; the canal, 48 feet wide and 5 deep, for $2,056; and the largest, for $3,040 per mile.

If these several sums be compared with the lowest estimated cost of a railway of two tracks, laid on stone sills, the ratio of the cost of such a railroad, to that of the smallest of these three canals, is as $13,000 to $1,845 or near 7 to 1; of the 2d, as $13,000 to $2,056, or near 6⅓ to 1; and, of the largest, as $13,000 to $3,040, or near 4¼ to 1.

Such, therefore, is the proportional cost of the cheapest practicable canals, of the above dimensions, when compared with the cheapest practicable railroad of two tracks, laid on stone sills, where stone is very convenient.

But it may be truly said, that it is very rarely, if ever, that a canal passes over ground, as favorable, as that assumed above. To this, it may be as truly replied, that a railroad can as rarely be constructed, without any graduation whatever of the surface of the earth, or any expense of masonry. Of the actual canal, along the Potomac valley, already constructed, the cheapest mile, as will be seen in the second table of the third annual report, consists of the 46th and 47th sections, on both of which there was paid an extra price for the transportation of a part of the earth forming the embankments. This mile cost $4,064, or less than a third of the cost of the cheapest mile of two tracks, upon stone sills, of the Baltimore and Ohio railroad, allowing nothing whatever for its graduation or masonry.

If this comparison, although founded on actual experience, be objected to, on account of its assuming, as its basis, the most favorable ground both for canals and railroads, then, let the most costly mile, on these two lines of communication, be compared; and, although the disparity will be by no means so great, the dearest mile of this large canal, consisting of its 17th and 18th sections, in which an ascent of 48 feet is overcome by six locks, costing about $10,000 each, will be found to have been less expensive, by 35 per cent., than the mile composed of the 4th and 5th sections of the first division of the Baltimore and Ohio railroad, or the single mile a short distance to the west of the former, consisting of a part of the 8th and the 9th sections of the same division of this road.

If a series of connected miles of the railroad and canal be preferred for the terms of this comparison, let the 13 miles composing this first division of the former, be compared with any thirteen consecutive miles of the most expensive part of the canal, and the railroad will be found to have cost more than the canal, in the ratio of near 4 to 3.

If, however, this be also objected to, because of the great cost, so far, of both works, take their corresponding and cheapest portions after climbing the granite ridge pierced by the Potomac and Patapsco rivers, as from the 38th section of the canal, up to the "Point of Rocks," being a distance, along the Potomac, of 47 sections, making, together, 24 miles. The cost of the grubbing, excavation, embankment, puddling, walling, and extra work

of the 24 miles, amounts to to $285,960, or $11,876 50 cents a mile; to which, adding for a granite aqueduct, of 7 arches of 54 feet span each across the river Monocacy, costing singly $96,000; for 30 culverts and 3 cut stone locks, with their appurtenant houses, in all, $171,847, or an average of $7,160 03 cents a mile; and the average cost of the 24 miles will be $19,036 53 cents, exclusive of such contingencies as are applicable to both works. Allowing, for these, ten per cent., they will swell this average to $20,940 18 cents per mile. Of this cost, but a very inconsiderable part now rests on mere estimates, the work on the canal, except the Monocacy aqueduct, having been very nearly completed at the date of the annual report, from which, the basis of this calculation is derived.

Recurring, in like manner, to the last annual report, made by the President and Directors of the Baltimore and Ohio Railroad Company, it will be found, that, allowing nothing for the necessary fixtures to surmount the inclined planes at Parr's ridge, for neither toll-houses, nor depots, nor for the cost of a wooden, instead of a stone bridge, across the Monocacy river, near which, it seems, there is no stone; nor for the fact that five-sixths of the whole of this part of the railroad is hastily laid on wooden sills, it is stated in this report, distinctly, that its graduation and masonry alone will cost $8,532 16 the mile, for the distance of 54⅝ miles above Ellicott's mills, or 13 miles from Baltimore, and that the other charges will amount to $11,628 per mile, if computed at the average cost per mile, of a double set of tracks upon the entire stem of the road, (67½ miles,) and of a single track, on the lateral road to Frederick, (of 3½ miles,) being one-third laid with stone rails, (i. e. including the first division of 13 miles,) and the remaining two-thirds, of wood.

From the one-third laid on stone sills, should be deduced the 13 miles next to Baltimore, leaving, out of the entire 58 miles above Ellicott's mills, including the single track to Frederick of 3½ miles, but about 9 miles, or one-sixth of this road laid on stone sills.

Adding the $11,628 a mile, which is somewhat more than the average cost of a double track on wooden sills, to the $8,532 16, the average cost allowed for graduation and masonry, and the sum total of the cost per mile of this road, is $20,160 16. But if the expense of the fixtures at Parr's ridge, estimated at $40,000 in another part of this report, be added, and, with it, the further cost of toll-houses and depots, this average will be swelled to a sum exceeding, without any allowance for contingencies, the cost per mile of the canal; and let it be remarked, that, of this average cost, a large proportion is founded on mere estimates of expenses yet to be incurred. If a due allowance be made for a bridge of stone arches over the Monocacy, instead of a wooden superstructure, and for the substitution, hereafter, of stone for wooden sills, where stone is said to be difficult to be procured, and for contingencies also, the railroad will be found to exceed the canal, in cost, by near the same per centage, on the more easy, as on the more difficult parts of the routes of the two works. Nor should it be forgotten, that this last comparison is of a railroad through an open country, allowing a choice of way, for a work, not confined to a certain inclination in the mile; while the canal must, of necessity, hug the parent of its existence, the Potomac river, and cross all its tributary streams, where widest and deepest, because near their mouths.

When the railroad shall have entered the valley of the Potomac, and encountered the same disadvantages with the canal, its masonry as well as its graduation, will rise in cost much beyond the estimate here admitted.

So much for the *relative cost of these works*, which, for many reasons,

That a load of the former is more elastic, and, therefore, less injurious to the road. This objection is met by the greater velocity with which they are transported, the greater number of wheels which they bring in contact with the road, and its greater injury, from the friction of those wheels. On these considerations is founded, no doubt, the higher charge for passengers.

Assuming 4½ cents, per ton per mile, to be the actual measure of that part of the expense, shown by the superintendent of transportation on this road, to have been involved in the carriage of persons and property upon it, in the first nine months of the current year; and adding, as is warranted by the report of the superintendent of the Mauch Chunk railroad, $1\frac{16}{100}$ cents per ton per mile, for the repairs of the carriages; and, as the former road is of much better quality than his, only half a cent a ton per mile, or one-half of his estimate, for its repairs, there will result 6 cents a ton per mile, as the cost of transportation, in an experiment of nine months, on the first 13 miles of the Baltimore and Ohio railroad, the materials of which were all new, and as perfect as the expenditure of 60,000 dollars a mile, the cost of this part of the road, could make them.

The conformity of this *estimate*, which is by no means exaggerated, to the acknowledged cost of transportation, for the first six months of the same period, on the equally new, and much more costly, and, it is presumed, more perfectly constructed Liverpool and Manchester railroad, greatly confirms *its* probable truth.

A brief transcript of the Mauch Chunk Courier, from the annual report laid before the stockholders of the Liverpool and Manchester railroad, at their meeting in September last, gives, for the gross receipts on that road, for the first half of the present year, from the carriage of persons alone, £43,600 7*s.* 3*d.*; for merchandise, £21,875; and for coals, £218 6*s.* 2*d.*; making the total amount of gross revenue £65,693 13*s.* 7*d.*; from which is to be deducted the sum of £35,379 for the gross expenditure involved in the collection of this revenue, including an inconsiderable land tax, (the stock is free of all assessment by the charter,) and a sum, not stated in this transcript, paid for interest on an outstanding debt of the company. The nett revenue for the half year, was, as there stated, £30,314 13*s.* 7*d.*, on an investment of capital exceeding £800,000 sterling, or, very near, it is believed, 4,000,000 of dollars, making due allowance for every thing, and including the difference of exchange between English and American currency.

Although neither the sum paid as land tax, nor the interest included in the six months disbursements, is stated in the extracts from this report, here quoted, at second hand,* they supply the following particulars, which answer the same purpose: That the actual receipts "for the goods carried," were equal to 10¼ shillings sterling, about 245 cents per ton, for the entire road of thirty miles, (stated in a late work to be 29¾ miles,) and that the expense chargeable on their transportation, amounted to 7*s.* 7*d.* a ton, about 181¼ cents; leaving 2*s.* 8*d.* per ton, or 63¾ cents, as the profit on the stock of the company; and making the total cost of transportation six cents a ton per mile, on this new, truly magnificent, and, it is presumed, perfectly constructed railroad of two tracks, laid on a solid foundation of stone. The receipts for passengers, in gross, £43,600 7*s.* 3*d.*, amounted to 4*s.* 7¼*d.* each; and the expenses of their transportation to 2*s.* 6¼*d.*; making the nett

* The entire report is added to this document, and is correctly quoted above.

profit, on *each passenger, 2s. 7d.*; or very near the same as on *a ton* of goods.

What, though not immediately connected with the present inquiry, is well worthy of notice, in passing along, is that the receipts for passengers doubled the receipts for the transportation of property. That the total sum received for the latter, indicates the whole tonnage of goods, for the six months, not to have much exceeded 40,000 tons, which, doubled for the year, makes but a fourth of the tonnage of the Erie canal of New York; and that this road, from the second sea port to the largest manufacturing town in England, through a country abounding in coal, the source of the greatest revenue on the most profitable lines of inland navigation in Great Britain, yielded, in six months, for the carriage of this primum mobile of all the British work shops, but £218 6*s.* 2*d.* sterling.*

The present object, however, for introducing the preceding facts, is to confirm, as they undeniably do, the estimates made by the highest American authorities, of the *relative cost of transportation* on railroads and canals, by reference to the most perfect railroad that has yet been constructed—it may be added, over favorable ground, in a country where manual labor is so cheap that it can be economically employed to sweep the road; where the arts have reached the greatest degree of improvement, and their ingenuity has been excited by high rewards, to invent and construct the most

* How small a part of the imports of Manchester, through Liverpool, is comprehended in these 40,000 tons, which comprehend the trade both to and from that sea port, will be the more apparent from the following description of the trade of the former, from the Edinburgh Gazetteer, published in 1822, vol. IV. p. 135.

"The greater part of the cotton trade of Great Britain centers in Manchester, extending around in all directions, to Furness on the north and south, and to Leeds and Liverpool on the east and west." The various branches of the manufacture are carried on more or less through all this district, but by far the most extensive, especially the spinning, in Manchester. Manchester is, besides, the general depot from which the raw material is distributed through all parts of the district, and in which all this scattered merchandise is again collected, when finished, into a centre, to be again expanded over a wider circle."

Though various causes have concurred to render Manchester a great emporium of manufactures, the foundation of the whole is unquestionably laid in the natural situation of the place, on the banks of a navigable river, in the midst of inexhaustible fields of coal, near the centre of the kingdom, and capable of having its external and internal communications greatly improved by art.

"By means of the canal which proceeds from it to different parts of the country, Manchester enjoys a communication, by water, both with the eastern and western seas, being situated directly in the line of navigation which here extends across the island from shore to shore; while it is equally open to the north and south by various branches from the main trunk. The Irwell and Mersey form an easy access to Liverpool. The act for making these rivers navigable, passed in 1720; and, in 1755, this communication was still more facilitated by the famous canal of the Duke of Bridgewater, from the Duke's coal works to Manchester, and from thence to Runcorn, which, at the same time, uniting with the grand trunk, or Staffordshire canal, extends the navigation southwards to the Trent and Severn, to Nottingham, Birmingham, and Bristol.

"In 1795, 25 boats, of 55 tons each, were employed on the Mersey and Irwell, plying between Manchester and Liverpool, and making 36 trips a year; and on the Duke of Bridgewater's canal there were 42 boats of 50 tons each, which made 80 trips a year." "The Leeds and Liverpool canal runs greatly to the north of Manchester." "On the north, the Duke of Bridgewater's canal is prolonged by Leigh, to the Leeds and Liverpool canal, near the coal district of Wigan." Under the Liverpool head, vol. III., page 786, it is said, "The Duke of Bridgwater's canal, begun in 1761, had opened a communication to Manchester much superior to that of the Mersey and Irwell." Yet the annexed table, showing the value of the stock vested in the former navigation to be 5¼ times its original cost, and its dividend, 20 per cent., proves that, though inferior in value to the public, it finds, no doubt, at cheaper rates of transportation, very extensive employment.

In 1819, the *tonnage* of Liverpool was 867,318 tons, or more than that of the whole United States of America at the same period. The duties on *it* amounted to £110,127 1*s.* 8*d.* sterling.

perfect locomotive engines; and where the coal which gives these engines motion, is so cheap as, under the obligations of a charter, to be sold seven miles from the pit, in the town of Manchester, at 3½*d.* for a bushel of seven score, which is at the rate of 2*d.* sterling for the Pennsylvania bushel of 80 lbs. weight.

Ten shillings sterling, or about 240 cents, American currency, was the price to which the undertakers of this enterprise bound themselves to reduce the cost of transportation between Manchester and Liverpool, being, as has been shown, 8 cents a ton per mile. But the cost of this reduction is found to consume, *for carriage only*, rather more than three-fourths of this sum; or to exceed 6 cents a ton per mile; leaving but 2 cents a ton per mile to pay the interest on the capital invested in the road, and its necessary appurtenances; which falls little short of 4 millions, and may, possibly, be found to exceed that amount; allowing nothing for the interest lost during the six years' progress of this very heavy expenditure.

Here, again, is seen, a verification of the results of the experience of the ingenious superintendent of the Mauch Chunk railroad; who, long since, informed the public, that while a velocity of fifteen or twenty miles an hour (which he, then said, could be extended to sixty,) was very easily attained, and actually attempted on that railroad, such was the injury occasioned to the cars and the road, from such rapid motion, as to render the transportation, nearly as costly, as on an ordinary turnpike.

The description given by travellers lately returning from England, of the ruins of cars and rails scattered along the margin of the Liverpool and Manchester road, farther corroborates Mr. White's statement; although it is very evident that, while so large a proportion of the revenue of this railway is derived from the carriage of persons, they must be offered the attraction of quick motion and economy of time, to tempt them to pay the fare of five shillings for travelling on a railroad, the same distance, for which they would pay, on a canal, less than a moiety of that sum. Mr. Fairbairn states, in a work quoted in a former note of this appendix, that two pence a head would pay the expense of the mere carriage or trackage of persons, exclusive of tolls, through the fifty-four miles of canal navigation between Glasgow and Edinburg.

That so little merchandise is transported on the railroad from Liverpool to Manchester, between which, the water carriage used to be fifteen shillings sterling a ton, either by the Mersey and Irwell* navigation, or by the river Mersey, for sixteen miles, and the Duke of Bridgewater's, now the Marquis of Stafford's canal, of twenty-nine and a half more, is, without doubt, to be ascribed to the breaking up of those profitable monopolies, and the recent reduction of the price of carriage, on both those lines of water communication. But that, in this competition, the victory must ever remain on the side of the cheaper intercourse, by water, is evident, from two considerations: first, that on the same portion of any improved canal communication

* The Mersey and Irwell navigation, above Runcorn gap, is mixed of still water, produced by dams and locks, and occasional canals.

A third line of navigation, though much more circuitous than either of the above, may also be said to connect Liverpool with Manchester. It is the Liverpool and Leeds canal, and the cut from Wigan, by Leigh, to Worsley mills, and thence, to Manchester, by the first canal constructed by the Duke of Bridgewater, which now crosses the Liverpool and Manchester railroad, within a mile and a half of those pits; whence, by the obligations of his charter, that enterprising nobleman was compelled to deliver coals, at Manchester, distant seven miles from their entrance, at about four cents for the Pennsylvania bushel.

in America—and it cannot be less true in England—ninety cents would pay the reasoable toll, as well as freight, on the carriage of a ton of goods for thirty miles; and 135 cents, for a distance, equal to the entire voyage of forty-five miles, from Liverpool to Manchester, by the circuitous route of the Bridgewater canal and the river Mersey: and next, that the imposing opening, and very near twelve months' use of this very costly railway, so far from reducing the antecedent revenue of the Mersey and Irwell navigation, has enabled its proprietors to recover from the panic of the years 1828 and '29, and to augment their dividend from 35 to 40 per cent., or to five per cent. beyond its extent ten years ago. (See the table, post.)

The price of their stock has, in that time, it is true, fallen from 8¼ to 5¼ times its original cost. This depression may, also, be temporary; though, much for the public benefit, canals will, hereafter, be compelled, by the wholesome competition of railroads, to reduce those exorbitant profits, which injudicious charters, framed without any limitation, but in the maximum rate of tolls, have hitherto allowed them to divide.

It has been already noticed, that the charter of the Chesapeake and Ohio Canal Company, pursuing the policy of the act establishing the Virginia fund for internal improvement, limits the profit of their stock to fifteen per cent. per annum; a regulation to which no just exception can be taken; for, while the receipts of a canal will always be proportioned to the magnitude of its tonnage, its wear and tear, or annual outlay for repairs, will not. In this respect, as in so many others, canals have, obviously, great advantages over the best railroads; the repairs of which must be proportioned to their use, and increase with their gross revenue.

The last annual report of the Liverpool and Manchester Railroad Company confirms the preceding rumor, so extensively circulated in the United States, that the Bolton Bury and Manchester Canal Company, have obtained the consent of the British Parliament to substitute a railroad for their present canal.

To rebut the inference already drawn from this solitary fact, to prejudice the American public against all canals, there is subjoined, to this note, a late essay from a public gazette, which, while it demonstrates the expediency of this substitution, as conclusively proves, that no general inference can be deduced from it, to the prejudice of inland navigation, when compared with railroads.

Conclusively, as the preceding facts, derived from the joint experience of England and America, appear to settle the relative merits of railroads and canals, it is probable that, while the present delusion on this subject, so generally pervades both countries, immediate assent will not be yielded to their force.

Canals can be constructed only where a sufficient supply of water exists to fill them. They must pursue the valleys of those rivers whose fountains feed them. Railroads, on the other hand, naturally seek the driest plains, avoiding, where practicable, water courses and alluvial lands. They have an ubiquity of locomotion which adapts them, if not to the real interests, to the illusory hopes of villages, towns, and cities, which no canal can ever be expected to reach: and those who advocate their exclusive use, know, full well, how to profit by this quality. Hence, a whole country may be set in commotion, by promises of railroads to intersect it in every possible direction. Such is the present excitement in the United States. Such has been recently, and, perhaps, continues to be, the excitement in England: such

was once, the excitement, though it soon subsided, in the same country, at the time of the completion of the Croydon railroad, in the county of Surry.

This road was finished in 1802, under the eye, almost, of her great commercial and political metropolis; for its distance from the capital of the British empire is but eight miles; and it is crossed by the public highway, between London and Epsom, a village of no little note, for its periodical races, its mineral waters, and the beautiful scenery of its neighborhood.

Yet, a very short period ago, (less than two years,) no railroads stock had reached an advance of one hundred per cent. above par, in the English market; while the following were, at that time, the prices of the several canal stocks comprehended in the subjoined table.

The annexed table of the prices of canal and railway stocks, in the London market, at various times, is composed, in part, from the trade list of the day, which is published weekly, by an assistant clerk of the bills of entry of the British customs, and may be, consequently, deemed to have an official sanction.

The table comprises only thirty-five, of more than one hundred canals, in Great Britain, and those the most profitable.

This table furnishes the best, because incontrovertible evidence, of the estimation of canal stocks, in England, at the several periods to which it refers, between March, 1821, and November, 1831.

DESCRIPTION and statement of the Prices of the Stock of

Names of the several Canals and Lines of Navigation.	Original cost of each share, in pounds sterl'g.	No. of shares.	Price of ea. share in 1821.*	Dividend on each share, at that time.	Price of the same in March, 1828.	Dividend at the same time.	Price of ea. share in Jan. 1831. (Trade List.)
	£. s.		£.	£. s. d.	£.	£.	£.
Ardrossan - -	-	.	-	-	-	-	-
Barnesley - -	160	5,720	300	13	-	-	215
Birmingham - -	17 10	4,000	203	12 10	565	20	270
Bolton and Bury - -	250	477	-	-	-	-	106
Carlisle - - -	50	1,600	490				
Chesterfield - -	100	1,500	150	8	120	8	170
Coventry - - -	100	500	1,200	44	999	44	800
Cromford - - -	100	460	400	19	-	-	420
Derby - - -	100	600	150	7 10	-	-	130
Erewash - - -	100	231	1,400	72	1,000	58	700
Forth and Clyde - -	100	1,297	570	25	-	-	600
Glamorganshire - -	100	600	250	13 12 8	-	-	290
Grand Junction - -	100	11,600	307	13	218	9	243
Grantham - - -	150	749	215	9	-	-	210
Leeds and Liverpool -	100	2,897$\frac{3}{4}$	395	16	278	10	395
Leicester - - -	100	540	325	17	260	10	220
Loughborough - -	100	70	4,000	200	2,400	119	1,800
Milton Mowbray - -	100	250	240	11	170	8$\frac{1}{2}$	200
Mersey and Erwell -	100	500	825	35	650	30	600
Monmouthshire - -	100	2,409	215	10	-	-	239
Monkland - -	100	101	-	-	-	-	90
Neath - - -	100	247	350	15	-	-	300
Nottingham - -	150	500	290	12	-	-	290
Oxford - - -	100	1,786	670	32	640	32	500
Shrewsbury - -	125	500	210	10	-	-	250
Shropshire - -	125	500	135	7	-	-	140
Somerset Coal - -	50	800	170	10	-	-	166
Stafford and Worcester -	140	700	800	40	642	40	760
Stourbridge - -	145	300	220	12	-	-	220
Stroudwater - -	150	200	450	23	-	-	480
Swansea - - -	100	533	280	12 10	-	-	230
Trent and Mersey -	101	2,600	820	37 10	900	75	620
Warwick and Birmingham	100	1,000	265	12	210	11	220
Warwick and Napton -	100	980	205	12	235	10	220
Wyrley and Essington -	125	800	160	6	-	-	115

Prices, at the same dates, of the Stock

Liverpool and Manchester	100	5,100	-	-	-	-	181
Cromford, High Pt. -	100	1,600	-	-	-	-	-
Canterbury - -	50	500	-	-	25	-	25
Cheltenham - -	100	330	-	-	78	-	78
Croydon - - -	65	1,000	-	-	-	-	-
Jersey - - -	60	1,000					
Severn and Wye - -	50	3,762	-	-	23	1 11	19 10
Forest of Dean - -	50	2,500	-	-	45	2 16	45
Stockton and Darlington -	100	1,000	-	-	160	5	200
Monmouth - -	50	553					
Clarence - - -	100	1,500	-	-	-	-	40

* Price in 1821, from the Monthly Magazine, transcribed from the Report of the Ohio "From the above it appears that canal stocks in England, of the medium original cost of worth £9,287, more than six times their original cost."

certain Canals and Railways in England, at various periods.

Dividend at the same time.	Price of ea. share, Nov. 1, 1831. (Trade List.)	Dividend at the same time.	Length of each Canal, in miles.	Lockage, in feet.	Cost, in pounds sterling.	Date of completion.	REMARKS.
£. s. d.	£.	£. s. d.			£.	Anno.	
-	-	-	33½	170	253,000	1799	
10	210	10	14	120	97,000	1812	
12 10	244	12 10	22½	204	115,000	1772	
6	106	6	15	187	97,000	1797	
8	170	8	46	380	160,000	1776	
44	750	50	27	96	120,000	1790	
19	410	19	18	80	80,000	1794	
6	120	6	9	78	90,000	1794	
70	600	54	11¾	181	-	1797	
27	600	27	35	321	421,525	1790	
13 12 8	290	13 12 8					
13	235	13	93½	760	2,000,000	1805	
10	195	9	33¾	148	124,000	1799	
20	405	20	130	841	600,500	1774	
13 10	211	17	21½	230	84,000		
180	2,550	180	9½	41	-	1776	
2 10	190	2 10	-	-	-	-	Navigation.
40	525	40	-	-	-	-	Navigation.
12	208	12	17¾	1,057	275,330	1796	Inclined planes.
-	90		12	96			
18	300	18	14	-	35,000	1798	
12	245	12	15	-	-	1802	
32	510	32	91½	269	330,000	1790	
11	205	11	17½	155	70,000	1797	Inclined planes.
8	140	8	7½	453	47,500	1792	
10 10	160	10 10	8½	138	185,000	1802	
36	555	36	46½	394	100,000	1772	
11	220	11	5	191	30,000	1776	
23	480	23	8	108	20,000	1796	
15	203	15	17½	366	90,000	1798	
37 10	620	37 10					
12	230	12	25	-	180,000	1799	
12	210	12	15	-	130,000	1799	
6	115	6	23	270	160,000	1794	

of Railways, in England.

-	205	8	29¾	-	800,000	1830	
-	20						
-	35						
-	78						
-	-	-	-	-	-	1803	
1 2	17	0 17					
2 10	33	2 4					
-	230	6					
-	65						

Canal Commissioners, of January 21st, 1824; to which they add the following remark:—
£1,525, pay a medium dividend of £485, exceeding 31¾ per cent. per annum; and are now

Of the lines of water communication described in the preceding table, that of the Mersey and Irwell navigation, and one other, not included in the table, because its stock, the property of a single individual, (the Marquis of Stafford,) is not in market, are the channels of trade, with which the Liverpool and Manchester railroad enters into immediate competition.

The extension of this railroad from Manchester to Leeds, and to London, would extend its competition to several other canals included in this table, as the Leeds and Liverpool, Grand Junction, Trent and Mersey, the Oxford, and to several others, less directly.

It is remarkable, however, that the prices of the stocks of the canals nearest to Liverpool, have fallen less, than those at a distance from it. While that of the Mersey and Irwell navigation had, in January last, sunk more than £300 on the share, its dividend, far from falling off, had risen 10 per cent. beyond that of 1828, and five above that of 1821. The price of its stock is still 5¾ times its original cost.

The Leeds and Liverpool canal stock, as well as dividend had, in like manner, risen, the latter 4 per cent. since 1821, and 10 per cent. since 1828, when the railroad had inspired the greatest alarm; the former, after falling at that period, from £395 a share to 278, mounted up again, and was selling on the first of November last, at £405 a share, or at more than four times its original price.

Of the thirty-five lines of improved navigation enumerated in the preceding table, the dividends of the stock of seventeen have been stationary, or very nearly so, for ten years past; six only have sustained any diminution; while as many have sensibly improved in value.

The Loughborough dividend, which was once £200 on the share of 100, and had fallen to 119, had, at the last accounts, again risen to 180, and its stock, which had exceeded £4000 the share, and fallen at one time to 1800, was, in the last month, at £2550 the share.

Although all the canal stocks in England have been affected more or less, in the estimate of their value, by the expected application of steam as the propelling power of railroads, and by the apprehended introduction of railroads in the immediate vicinity of all the most productive canals, but one canal in that country has, as yet, been proposed to be converted into a railroad, and that, from considerations very peculiar to itself.

These are so minutely, and it is believed, so correctly detailed, in a recent essay which appeared in the National Intelligencer, that it has been deemed expedient, as well as proper, to attach it to this note.

The length, lockage, and cost of the canals included in the preceding table, are derived from a work of unquestioned authority, by *M. Huerne de Pommeuse, membre de la Chambre des Députés*, originally written in French, and, it is believed, not yet translated into English. Its other facts are from the "*Trade Lists.*"

It is obvious, under the circumstances disclosed by this table, that railroad stocks, yielding, on the same amount of capital, a half, a fourth, or a tenth even, of the profit of certain canals, in the same neighborhood, would furnish profitable investments for money. And engineers of every description, therefore, and pamphleteers too, would not be wanting, after the canal system of that kingdom had been already pushed to the utmost limits of its land and water, to recommend railways in preference to canals.

The following receipts on certain American canals, charging for toll and transportation together, not more than three cents a ton per mile; two cents being the average toll, and one cent the price of transportation, deserve consideration here.

To show that a canal may be profitable, with a toll, not exceeding an average amount on its tonnage, of two cents a ton per mile, it may not be immaterial to notice the total amount of tolls on the New York canals, which have cost about $18,000 a mile, or about 7½ millions, and the Schuylkill navigation, the stock of which is now, at an advance in the American market, of near one hundred per cent. on the share of $100.

Extracts from the letters of Hamilton, containing "A brief view of the system of internal improvement of the State of Pennsylvania," by M. Carey, M. A. P. S., and of the Antiquarian Society, published in Philadelphia, in 1831.

"New York did not begin to collect tolls on her canals, except on a very small scale, before the fall of 1822, above five years from the time when they were commenced.

"Canal tolls, 1821,	$2,220
1822,	44,486
1823,	89,988
1824,	319,320
1825,	521,345
1826,	750,759
1827,	847,759
1828,	897,265
1829,	771,685
1830,	1,056,922
1831,	1,193,435"

The following are the chief articles that reached Albany, by way of the canal, in 1830:

Barrels of flour,	396,900
ashes,	25,670
provisions,	22,008
salt,	42,601
whiskey,	28,207
Hogsheads of whiskey,	1,420
Boxes of glass,	6,374
Barrels of lime,	2,404
Bushels of wheat,	209,011
corn, rye, and oats,	114,989
barley,	182,783
Cords of wood,	12,976
Feet of timber,	31,621
Shingles,	11,810,000
Feet of lumber,	25,832,142

"New York is destitute of coal, one of the greatest sources of canal tolls. She, it is true, derives a small supply of iron from the borders of Lake Champlain. But that the amount is insignificant, appears from the fact, that the total tolls of the Champlain canal, up and down, were, last year, only 89,053 dollars."

"The tolls of the Schuylkill Navigation Company, last year, were 148,165 dollars; of which, 87,195 dollars were received on coal, being about sixty per cent. of the whole."

The supplies not only of iron, but of lime, for manure, as well as cement, must depend on the vicinity of coal to the ore bank, and the quarry.

Increase of tolls on the Schuylkill Navigation.

Years.	Tolls on coal.	Total tolls.	Tonnage.	Price of stock: shares, $ 100 each.
1825	-	15,775	-	January, 1826, = 75 to 80
1826	-	43,108	32,404	" 1827, = 95 to 101
1827	33,317	58,149	65,501	" 1828, = 101 to 102½
1828	46,202	87,171	105,462	" 1829, = 100 to 101
1829	77,032	120,039	154,504	" 1830, = 160 to 165
1830	87,195	148,163	180,785	" 1831, = 176 to 180

The works of this canal "are, in extent, about 108 miles; commencing at the Lancaster Schuylkill bridge, and ending at Mount Carbon: of which 62 miles are by canals, and 49 by pools in the river. The number of houses for lock-keepers, is 65; the number of locks below Reading, 39; and above, 81; being, in the whole, 120, (of which 28 are guard-locks,) overcoming a fall of 588 feet."

In 1826, the amount paid for this improvement, was	$ 1,704,948 80
for land, - -	63,405 64
for damages, - -	39,701 73
Total cost, - -	$ 1,808,056 17

exclusive of interest on loans, and securities.

In the same annual report of this company, from which the above is extracted, is the following testimony in favor of large canals: "The pools having towpaths along them, are a very important, and, it is believed, when finished, will be a favorite part of the navigation, with those who use them; for it is a fact worthy of notice, that a horse, towing a boat, will, with greater ease, go at the rate of four miles an hour, in a pool, than three miles in a canal."

This proposition is in accordance with the experiments of the French academicians, on broad and narrow canals; and corroborates the policy which has given such enlarged dimensions to the Chesapeake and Ohio canal; while, in every other respect, the navigation of the eastern section of the Chesapeake and Ohio canal will be much less obstructed by locks, in proportion to its length, than the Schuylkill navigation; the stock of which is now near, or quite, 100 per cent. above par.

From the National Intelligencer.

"*Messrs. Gales & Seaton:*—To an impartial press, whatever tends to guard the public mind from delusion, and especially in relation to topics of national interest, must be acceptable.

"I confidently, therefore, anticipate your ready admission into your useful columns, of the correction of an error current in the gazettes of the United States, that canals are, every where in England, giving place to railroads: and, as conclusive evidence of this, that the Bolton, Bury, and Manchester Canal Company, have offered their canal for the site of a railway.

"The first position is no further true, than that, as almost all the canals that could be made, and many that ought never to have been made, have, long since, been constructed in England; and as some of them have proved the richest monopolies known to the world, railroads have, of late, arisen to compete with them, for a share of their dividends. These have been, and still are, so considerable, as to occasion an advance, on the original price of canal stocks, in some cases of a thousand, in others of two thousand, and three thousand, and in one case, of more than four thousand per cent.

"But, as I have suggested, very near, or quite half of the canals of England, having great lockage, little water, and less trade, have proved, from their very outset, to the present day, of little, or no value to the proprietors of their stock. This has, indeed, in some cases, so completely disappeared from the money market, that neither the weekly "*Trade*," nor any other "*list*" of prices, pretends to state what is its selling price.

"Examine, not the present merely, but the past condition of the canal, connecting Manchester with the towns of Bolton and Bury, since this is triumphantly adduced as a canal—the only one, indeed, so quoted, which has been offered, by its proprietors, as part of the site of a railway, to be constructed between Manchester and Leeds.

"This canal, I have seen: but I do not, for that reason, ask the least reliance on my authority for the facts respecting it, which I am about to state.

"Rees' Encyclopædia, the Encyclopædia Metropolitana, Bradshaw's maps of the canals and railways of the midland counties of England, and similar sources of intelligence, may be appealed to, for the verification of my statements: and, to them, I refer the reader.

"The canal between Bolton and Manchester, one of the straighest in England, is eleven miles long: the branch to Bury intersects it, three miles from Bolton, and is, in length, about four miles; so that, both together, being the property of one company, make 15 miles; and while the distance of Bolton from Manchester is 11, that of Bury from the same place is 12 miles.

"There are 12 locks on this canal, and two costly aqueducts over the rivers Irwell and Leven. It was fed, in 1799, by the former of these rivers, but in 1802 it was found necessary to construct a reservoir at Ratcliffe. Its construction exceeded in price 30,000 dollars a mile. The shares of its stock, in number 447, originally cost £250 sterling; were selling, as far back as 1824, at £112 sterling each; having then fallen below one half of their former price.

"The object of this canal was to reach Liverpool through Manchester, by the Duke of Bridgewater's canal, with which it is there united by means of the Medlock brook. From Manchester, the cheapest and safest water communication with Liverpool is by the Duke of Bridgewater's canal, of 29 miles, to Runcorn, where that canal enters the river Mersey, and thence, along the open bosom of that broad river, often too rough for canal boats, 16 miles more, to the harbor of Liverpool.

"The whole water communication of Bolton, with Liverpool, thus com-

posed, is therefore 56 miles in length. The cost of carriage, on the part of this line of intercourse, between Manchester and Liverpool, the memorial to the British Parliament, in behalf of the Liverpool and Manchester railway, stated to be 15s. sterling per ton; which that memorial promised to reduce, by means of the railroad, to 10s. a ton. The cost of carriage cannot be less, from Bolton, which, by water, is 11 miles farther than Manchester, from Liverpool.

"But the distance of Bolton, from Liverpool, *over land*, is less, by three miles, than that of Manchester from Liverpool, by the recently constructed Manchester and Liverpool railway. This railway, moreover, approaches within two and a half miles of the town of Leigh, at a point 17½ miles from Liverpool; and from Leigh to Bolton, a distance of about seven miles, a railroad has been already constructed, by authority of an act of Parliament, which passed in 1828. So that while the water communication between Bolton and Liverpool, mixed, circuitous and hazardous, is 56 miles in length, that, by land, is 27 miles, of which, all, but 2½ miles, consists of a highly improved railway;* and while the cost of transportation for a ton of goods, by water, from Bolton to Liverpool, does not fall short of 15s. sterling, that, by land, cannot exceed 10s. sterling.

"The same considerations apply with nearly equal force to the short branch to Bury, which is, a few miles, east from Bolton.

"It is not difficult, then, to account for the willingness of the proprietors of this canal to surrender it, for a railway, or any other purpose, to any one, who will take it of their hands, and pay them any thing for it.

"If, indeed, the carriage to Liverpool, *by water*, from Bolton, by Manchester, and *thence*, by the Duke of Bridgewater's, now the Marquis of Stafford's canal, and the river Mersey, which spreads out to great breadth, below Runcorn gap, a distance, in all, of 56 miles, could be reduced from 15s. sterling, or 3.60 cents, to 3 cents a ton, per mile, the entire cost of transportation of heavy commodities, on the canals of New York, Pennsylvania, and Ohio, then, indeed, the case would be not quite so hopeless for the Bolton canal.

"Ten shillings sterling, per ton, the price now charged, on the railroad, for transporting a bale of cotton from Liverpool to Manchester, a distance of 29¾ miles, measured from the wharf of Liverpool to the entrance of Manchester, if this sterling money be turned into American currency, with a suitable allowance for the difference of exchange, and the relative value of the metallic mediums of the two countries, is not less than $2 40 cents, or eight cents a ton per mile, for transportation; a charge not too great, considering the cost of the road, which is, now, known to have been, all charges included, about 140,000 dollars a mile.

"The American charges for canal transportation, at 2 cents per ton per mile for toll, and one for freight, which last is quite high enough, would reduce the cost of carriage on the line of 45 miles, between Manchester and Liverpool, to 1.35 cents the ton, or 1.05 cents less than the present charge on the railroad of 30 miles, between the same places; and adding 11 miles, or 33 cents, for the distance, from Manchester, to Bolton, still, the advantage, excluding any allowance for the danger and delays, of 16 miles of open river navigation, of the water, over the land transportation, between Bolton and Liverpool, would be 72 cents on the ton; or quite enough to keep the carriage in its old track.

* Leigh is now connected with the Liverpool and Manchester railroad, by a railway.

"As to the river Mersey; from Runcorn, it is open to every one. What the Marquis of Stafford may charge, on what was once the Duke of Bridgewater's canal, subject to the restraints of the charter, under which he holds his title, it is for himself to decide. But if the exclusive advocates of railroads, either in this country or in England, find any cause for exultation in the preceding facts, let them rejoice! If they question the facts, let them adduce their conflicting evidence, and they shall again hear from

TRUTH.

A fair experiment of the relative utility of railroads and canals, would depend on so many circumstances, as regards their relative plans, location, cost, and species of traffic, that many years would be consumed in bringing it to a satisfactory conclusion.

In the first stages of such an experiment, a canal, liable to frequent interruptions from the unsettled state of its banks, would labor under great comparative disadvantages; while the railroad would possess the recommendation of being new, and, therefore, in its most perfect condition. Their relative profits would depend, of course, on the proportion of their nett income, to the cost of their construction, and the former subject of this comparison would, itself, depend on the expense of those very repairs, which would be diminishing, on the canal, as its bank acquired stability from time, and increasing upon the railroad, as use impaired its strength, by friction, frequent changes of temperature, and unforeseen accidents.

As to the relative speed of transportation on both, the decision of that question must await the equal use of both the canal and railroad, for a considerable period, and under various circumstances, by the same amount of tonnage. It is difficult even to conceive how a railroad, with but two tracks, and having both occupied at the same time, by numerous and heavy laden cars, moving in oposite directions, can admit of the velocity, which it is believed, a boat may attain, on a canal, without the slightest interference with any other vessels moving on the same surface, in opposite directions, and with different velocities.

Of the possible application of steam, to canals, not indeed, to such canals as those which so often occur in England, but to the canal of the Forth and Clyde, in Scotland, which has near the same breath with the Chesapeake and Ohio canal, a doubt can no longer be entertained, notwithstanding the numerous and very confident authorities cited to disprove it, by the Baltimore and Ohio Railroad Company; all of which, indeed, derive their whole force, as they doubtless do their existence, from their application to the comparatively narrow and shallow canals of England.

A reference to the able essay of the practical civil engineer superintending the Lehigh Coal and Navigation Company's works in Pennsylvania, who, having both a railway and a canal under his charge, with abundant experience, and no motive whatever to deceive himself or others, will shed more real light, on this inquiry, than all the British authorities united; and his suggestions of various modes of diminishing the expense, and of accelerating the speed of transportation on canals, while it evinces his mastery of his profession, may inspire a doubt, at least, whether *mechanical genius* may not hereafter find, as full exercise for its invention, in improving the navigation of canals, as in propelling railroad cars.

When, therefore, the appeal to public opinion will be so far settled, as to enable the Federal Government to decide a question, which now perplexes the civil engineer, cannot, probably, be determined.

One thing which is certain, appears not to have been generally known, that the Chesapeake and Ohio Canal Company depend on the prosecution of their work, above "the Point of Rocks," for a supply of water to five and twenty miles of their canal, now nearly completed, below that point, and, therefore, that the result *of the experiment which has been recommended,* could not be patiently awaited, by that company, without most serious loss to their stockholders, and to the public.

If, as two of the most eminent civil engineers have said, after careful inquiry, the internal intercourse of England be not sufficiently active to warrant the use of *stationary steam engines*, on such a railroad, as that between Manchester and Liverpool, the cost of which, it is ascertained, exceeds $130,000 a mile, it must be manifest that the United States cannot, in the present state of their population and commerce, avail themselves of the cheapest propelling power applicable to railroads.

Whether America be ripe for the profitable employment of *locomotive engines* between her chief cities, or between those cities and the country which sustains them, is a question yet to be tried and determined, by experience. If mere animal force be, at present, the most economical moving power on railroads and canals, then, their relative value is admitted to be unequivocally settled in favor of the latter.

Railroads are universally acknowledged to be greatly superior to all other roads; and the time may and probably will arrive, in the United States, when constructed with many tracks, for carriages moving at the same time, with different velocities, in the same, as well as in opposite directions; and propelled by *stationary engines,* having sufficient occupation to sustain their constant and therefore profitable use, railroads will prove formidable, if not successful rivals of canals. In the interim, it cannot be wise, or prudent, to arrest the improvement of a country, by institutions suited to its actual condition, because it is expected that, at some future and distant period, these may be superceded, by inventions of more expensive structure and costly use.

In the progress of navigation, the floating raft, the bark canoe, the open boat, and the decked vessel, varying in size, from the light sloop which scuds along the coast, to the magnificent Indiaman, or the awful battle ship which braves the ocean and the storm, have all their appropriate places.

Indulging similar views of the future march of invention, should it so happen in process of time, as there is much latitude for hope, if not sufficient ground for confident prediction, that, by the introduction of steam power on canals, or the use of a part of their surplus water to propel their boats, on the principle of the action of the stationary engine on the railway, the expense extending canal navigation may be greatly reduced, and its velocity be proportionably accelerated, the spirit of liberal and enlightened competition which railroads have recently awakened both in Europe and America, will yield to commercial and social intercourse, to the union of States and the happiness of their people, as substantial benefits, as if the most flattering promises of their exclusive advocates had been fully realized.

The following impressive caution against rash speculations in railroads, is given in a publication, entitled "an account of the Liverpool and Manchester railway, by H. Booth, esq., treasurer to the company."

"The Liverpool and Manchester railway is a magnificent work; but it will be useful to keep in mind that such works cannot be executed except at an expense of no ordinary magnitude. This railway will cost above £800,000, including the charge for stations and depots at each end, and machinery, wagons, &c., for a carrying department. The immense traffic between Liverpool and Manchester amply justifies this outlay. But, with reference to any similar scheme in extension of the railroad system, it is desirable the projectors should impartially calculate the cost of the work, as well as the income it may be expected to produce; and, especially, that they should make an ample allowance beyond the first estimate of the expenditure, before they embark in the undertaking."

In an address to the members of both Houses of Parliament, from which the above is transcribed, the following very pertinent remarks appear:

"Whatever hope and encouragement for the future may arise out of the trial of the Liverpool railway, now going on, especially as respects the consistency of speed with safety, it cannot be pretended that sufficient proof has yet been given of the main point, required to establish the superiority of railways over canals, viz.—their GREATER ECONOMY. Of this, the reduction in the tonnage of raw cotton, in which the railway has been followed by the water carriers, is no proof; because the rate now charged, within one shilling per ton, was fixed by the railway act, at a time when the cost of its conveyance could only have been approximated by an estimate. Unless however, the cardinal point of greater economy can be clearly made out, the advantages of the railway will be limited, (as is still the opinion of many of the best judges) to those cases, in which an extra-price can be afforded, for the rapid conveyance of passengers, and of those lighter articles of merchandize which are required to supply immediate demands. The proof which is required must consist, not in ESTIMATES OR CALCULATIONS; for, of the fallaciousness of these we have already had sufficient experience in the case of the Liverpool railway, the cost of which (upwards of £30,000 per mile) is more than double the estimate;—but in *bona fide* evidence, to be derived, at a fit season, from a fair winding up of the accounts of the concern;—from a balance sheet proving that, after paying interest on the sunk capital, and defraying the current expenses, there will be a surplus of actual profit, however moderate, to be divided among the proprietors. Such an investigation, it is obvious, cannot be entered upon at present, with any trustworthy result. It will require that the railway should be completely finished;—that the sufficiency of the work should be ascertained by longer experience;—that the solidity of the foundation, the durability of the road and embankments, should be fairly tried;—that the wear and tear of the rails, carriages, and machinery, should be determined, both under the present system of exclusive use by the company of proprietors, and when thrown open, as carriers in general. These, and a variety of other data, hitherto unknown, must be acquired by actual experience, before it can be pronounced, with just confidence, that railways can carry at a cheaper rate than canals. They are points upon which directors and engineers can at present offer nothing but random conjectures, quite unworthy of being made the ground of undertakings, which will absorb many millions of the capital of the nation."

A reference to the last annual report of the Baltimore and Ohio Railroad Company, in order to ascertain the cost of transportation on that road, as well as of its construction.

The last report of the Pennsylvania Canal Commissioners quotes from the late annual report of the Baltimore and Ohio Railroad Company the estimated cost of their road, and states it to be 27,228 dollars per mile. They notice, that, of the 71 miles of this road, so estimated, no less than two-thirds are laid with wooden sills, or rails, and that the branch to Frederick, of 3½ miles, is of one track only; but they do *not* notice, that the viaduct of this road across the river Monocacy, over which the Chesapeake and Ohio Canal Company are constructing an aqueduct of white granite, is of wood resting on stone piers, and estimated at a cost, less by $1000 per mile, on the entire railway, than the cost of this stone aqueduct; nor do they notice that no charge whatever is made, in the above estimate, for the fixtures and machinery of the inclined planes at Parr's ridge, which are, however, as necessary a part of the road, as a lock is of a canal.

The Pennsylvania Commissioners, also, remark, that this company admit "that it required 6½ months to lay down 6 miles of stone track," and "that the cost of laying with stone has been underrated in every instance," but they do not remark, that the reason given by the Railroad Company, in their last annual report, for not using stone on two-thirds of their road, or on their Monocacy viaduct, is, that the adjacent country could not supply it; and, if this be true, to replace, hereafter, the wooden, by stone rails, must be a work of much enhanced cost.

Making due allowance for all these considerations, it cannot be deemed unreasonable to estimate the construction of the Baltimore and Ohio railroad, when made of durable materials, and with two tracks, at a cost not less, at any rate, than 30,000 dollars a mile.

It would have been very gratifying to public curiosity, if the annual report of this company, made early in October last, had either stated the amount of the dividend of profit on the stock of the company, for the preceding year, which was done by the antecedent annual report, and then promised for every succeeding year; or that this report, which does state the gross amount received for transportation, had also stated the nett revenue of the company, from the 13 miles of the railroad, the only part which has been in common use, and the part, on which, the former dividend was declared.

This information would have cast some light on, by far the most important question remaining to be solved, at least in the United States, as to the *annual expenses* attending the transportation and repairs of railways, compared with canals. As to their *relative prime cost*, it is now to be presumed, that the current error which has hitherto prevailed on this subject, has been corrected by actual experience, the best test of truth in every branch of practical philosophy. Whatever may be the scientific calculations in Europe, the actual, as well as estimated cost, per mile, of the Maryland and Pennsylvania railroads, designed to consist of two tracks only, exceeds the average cost of their canals.

With regard to the only railroads in America, in relation to which we have any disclosure of the annual cost of the repairs, and expenses of transportation, other than tolls, it must be admitted, on the concurrent authorities, already cited in this appendix, from New York and Pennsylvania, that

they greatly exceed the usual cost of repairs, and the long and well established rate of carriage on canals of ordinary dimensions.

In relation to the Baltimore and Ohio railroad, it is understood that every thing, respecting the original purchase and repairs of the cars, or vehicles for transportation, is under the care of a special committee of the directors, whose expenditure on these subjects, for the preceding year, does not appear in their late annual report Indeed, neither the gross revenue, nor the expences of transportation, between October, 1830, and January, 1831, appears in that report.

In a table of the aggregate revenue, from tonnage and passengers, from January, to September, (both months included,) of 1831, the gross amount stated to have been received is $27,249 74 cents, for passengers, and $4,155 50 cents, for tonnage; making a total sum of $31,405 24 cents.

In another table, under the head of "expenses of transportation," from which, might be inferred, but for the preceding report of the Superintendent, that the *total expenses* were meant, we have an analysis, which excludes the original cost of the carriages, and even the interest on that cost, as well as any estimate or charge for their repairs as well as those of the road itself. The recapitulation of those expenses furnishes,

For the undefined item of "*Moving power*," - -	$5,526	55
Drivers and engine men, -	1,763	45
Agents and conductors, -	1,901	32
Depot expenses, - -	1,066	39
Oil, - - -	254	98
Contingencies, - -	482	18
Making the total expenses of the preceding nine months,	$10,994	87."

On the 19th page of the report, "the *machinery* and *moving power*," are treated of under one head; but, if the phrase "*moving power*," applies to the animal labor, and also to the locomotive steam engines employed to propel the carriages, it is presumed that the *cost* of the carriages, and of their repairs, is not included in the above list of expenses; and so we are, accordingly, told by the Superintendent.

In the estimate accompanying this report, of the anticipated expenditures of the company, during the *ensuing* twelve months, "the construction of the necessary cars and locomotive engines is computed at $150,000." (See page 102 of the report.) Some expenses of a similar character must have occurred, *in the nine months of the past year*; but, after a diligent examination, it does not appear that any part of them have been charged upon the current receipts for transportation, or on the revenue of the year.

In like manner, the Superintendent of construction, on this road, in his report to the principal engineer, of the 30th of September, 1831, apprises him, that the "railway in the city and first division of the road has undergone a thorough examination, and *such repairs, as appeared necessary*, have been made:" and we learn from the 12th page of the report, that this first division extends to Ellicott's mills, or all the road in use. But there, nowhere, appears any statement of the cost of the repairs of this division, nor does the gross revenue, appear any where to be charged with them, or with any part of them. Yet, it is very obvious, that the actual cost of carriage on a railway, cannot be ascertained, without a due reference to those items of unavoidable expenditure.

Although, therefore, the annual report of this company explicitly states, that, "*upon reference to the report of the Superintendent of transportation, hereto annexed*, it will be seen, that 81,905 passengers have passed on this division, since the first of January last, and that, within the same period, 5931 tons have been transported upon it, yielding an income of $31,405 24 cents, and *involving an expenditure of* $10,994 87 cents," it is very evident, that *this is not the only expenditure involved*, in this transportation; and that, so far, the statement of the report is calculated to mislead the public judgment, as to the proportion, between the gross receipts, and the nett profit on the transportation of this railroad.

Indeed, the preceding statement of the President and Directors, in their annual report, is the more extraordinary, since the Superintendent of transportation, whose annual report to the President, is quoted by them, most expressly says, in the body of his report, that he has "exhibited a return of the actual expenditures by the company, under the head of '*expenses of transportation*,' amounting to $10,994 87 cents; but *these*, as will be perceived," he candidly adds, "do *not include any charges* for the *construction*, the *repairs*, or the *wear* and *tear* of *wagons and cars;* and he properly adds, as the reason, "that branch of the service of the company *being under the immediate care and superintendence of a committee of the board.*" A fact, to which, this is the only allusion, in their annual report.

In the "general remarks" of the engineer in chief of this company, on the 100th page of this report, he states, as a result of those "improvements on Winan's car," which have so greatly reduced the friction of railroad carriages, that "the working effort of a horse, on a level, would draw 18 *tons*, 2½ miles per hour."

Now, if these improvements have been introduced on this road, which cannot be doubted, we have against the authority of the engineer in chief, that of the *Superintendent of transportation*, who, on the 129th page of this very same report, says, "that for some months past, a *series of experiments* have been made, with the view of ascertaining, *practically*, the *force of traction*, at a *slow draft*, *horses* can exert, *consistently with the preservation of their vigor and health.* It has been found that, graduated, as this road is," (its graduation and masonry alone, the same report states to have cost $46,354 56 cents, per mile,) "and each horse moving 3 miles per hour, he can traverse the 13 miles westwardly with 7 tons, and returning he can transport 10½ tons." In going, let it be remarked, the horse reaches a higher plane, in returning, he descends to a lower.

The Superintendent's report corresponds with the British authorities on the same subject; but, if the *maximum* power of a single horse, on a level railroad, when drawing Winan's improved car, be computed, as it has been, by *the engineer in chief* of this company, and it is very probable that he does not *underrate* it, since he makes it near twice the British estimate, still, the Chesapeake and Ohio canal has nothing to apprehend, from the exertion of animal power, on this rival railway; a single horse having drawn, at his usual walk of 2½ or 3 miles an hour, with apparent facility, more than fifty tons, on this canal, for many hours together.

By turning to the analysis made by Josiah White, the able director and superintendent of the Lehigh Coal and Navigation Company, it will be seen, that the annual repairs of carriages on the Mauch Chunk railroad actually amounted "to two-thirds of a cent a ton per mile;" while the same authority apprises the public, that the total cost of transportation, on the Erie

canal, "for boats of 40 tons burthen," is "one cent per mile, full loads one way and *returning empty.*" "Calculating on the same data, on a boat of 67 tons, (33 tons less than the burthen of those of the Chesapeake and Ohio canal,) such as will be adapted to the Delaware canal," he makes the cost of transportation "seven-tenths of a cent, per ton, a mile." The mere expense of the repairs of carriages omitted, in the last annual report of the Baltimore and Ohio Railroad Company, from among the items of the cost of transportation on their road, will, therefore, be found to exceed the *entire cost of transportation* on the Chesapeake and Ohio canal.

There remains, in fact, but one element of a just comparison between those works, to be ascertained by experience, to determine the relative economy of their use; that is, the sum required for their respective annual repairs, or to maintain against natural decay, and injury from use, the value of the fixed capital vested in them, respectively; that capital being, in fact, proved to be, very nearly, the same in amount. Railroads, as often, exceeding canals in their original cost, as they fall short; and the price of both being equally dependent on their location, and dimensions, and the peculiar character of the ground over which they respectively pass.

In further illustration of the relative cost of railroads and canals, the following extracts are made from the memorial prefixed to the appendix of Doc. 18, relative to the plan and probable cost of the Chesapeake and Ohio canal.

The condition of the Chesapeake and Ohio canal, and of the funds of the company, at the period of the general meeting of the stockholders in June last, is disclosed in the accompanying annual report of the President and Directors, to the stockholders, at their last annual meeting; in the annexed tables exhibiting the cost of its various works, and the report of the manner of their execution, made by Colonels Abert and Kearney, of the corps of United States' Engineers, to the Secretary of War, pursuant to an order of that department.

From these documents, it will appear that the construction of the canal has been completed as far west, as no legal obstacle opposed its progress; that, for forty eight miles above Washington, its various works had been, with scarcely an exception, faithfully executed; and that, between its first and second feeders, where the greatest physicial obstructions were to be overcome, its navigation has been long in active use.

From these facts, it may be inferred that the construction of the canal, but for the injunction of the Chancellor of Maryland, might, in the same time, have been carried, as far up the left bank of the Potomac, as the funds of the company would warrant; as it may, from the actual cost of the part which has been completed, that the expense of the whole eastern section, making but a reasonable allowance for the great enlargement of its dimensions, will not much exceed the estimate of Messrs. Geddes and Roberts, nor that of prior date, by the Central Committee of the Chesapeake and Ohio Canal Convention, from the proceedings of which, the charter of the present company originated.

Those estimates were applied, respectively, to three different canals, or to three several dimensions of a canal, passing, as nearly as practicable, over the same ground. The estimate for the first of these, having the same plan and dimensions with the State canals of New York, Pennsylvania, and

Ohio, viz. being forty feet at the surface, and four feet deep, and extending from Georgetown to Cumberland, a distance of 186¾ miles, amounted to the sum of $4,008,065 28, or $21,461 87 per mile; for one extending the same distance, and along the same shore of the Potomac, with a breadth of 48 feet at the surface, and a depth of 5, they computed at $4,380,991 68, or $23,191 38 per mile; and for a third, of the same depth with the second, but having, for 126 of the 186¾ miles, a breadth at the surface of 60 feet, and at bottom of 42, they computed at $4,479,346 73 or at $23,985 79 per mile.*

The difference between these estimates, when compared with the relative resistance to be encountered by the same boat, in passing along these several canals, induced not only a preference of the largest of the preceding plans, but an enlargement of that, to a depth of six feet. Accordingly, the canal placed under contract, and now nearly completed, is no where less than six feet deep; and, except for about three-fourths of a mile, made up of short spaces, here and there, at which, on account of peculiar difficulties, it is reduced in breadth to about fifty feet, its least width at the surface is sixty feet, and at bottom forty-two feet; affording a cross section of 306 feet. It may be proper, here to remark, that the cross section of the New York canals is 136 feet only, and that of the canal recommended by the United States' engineers, no where exceeds, and often falls short of 202½ feet.

The locks of the Chesapeake and Ohio canal are, consequently, one foot deeper, and being in their chamber 100 feet by 15, they are ten feet longer than those recommended by Messrs. Geddes and Roberts. They exceed in depth, to the same extent, those proposed by the United States' Board of Internal Improvement: and though less in length by 4 feet, they exceed the latter by 1 foot in breadth, being calculated for boats ninety feet long and fourteen feet eight inches wide, drawing four feet water, capable of carrying, each, one hundred tons, and of being propelled by the labor of two, or at most of three horses assisted by two men and a boy.

The breadth of this canal being about "four and a half times the breadth of the boat, and its cross section very nearly six times that of the boat, the latter will move with a moderate velocity, as on an indefinite expanse of water." But, the company extend their views beyond this result. Turning to practical advantage the rock which abounds every where along the line of the canal, and which has so greatly enhanced its first cost, they purpose, by walling its inner slopes, not only to obviate the necessity of future repairs, but, also, to fit this line of communication between the east and the west, for the use of steam, as its propelling power.

On the Chesapeake and Delaware canal, the breadth of which was designed to be sixty, and its depth eight feet, a velocity of seven miles an hour has been already attained by animal labor, and has superseded a resort to land transportation, for persons as well as property, across the peninsula between the cities of Baltimore and Philadelphia.

Economy, rather than velocity, being the great desideratum in the transportation to market of the very heavy and bulky products of the American forests, mines, and agriculture, the purpose of this canal would have been accomplished without looking to this powerful agent. By the efficacy of steam, however, combined with the enlarged volume of the Chesapeake and Ohio canal, passage boats, it is believed, may be expedited on its surface with a rapidity surpassed, at present, only on the best improved mail roads. In this anti-

* In the last of hese estimates, there was doubtless, a great error committed, if the first be assumed to be correct. Experience has shown that neither was so.

cipation, your memorialists make no allowance for those discoveries which are daily surprising the world with new applications of art and science to human use and comfort. They do, however, confidently rely on the very recent experiments on the Ardrossan, as well as upon the Monkland, the Union, and the Forth and Clyde canals of Scotland, referred to in the annual report appended to this memorial, which have demonstrated the fallacy of all former philosophical calculations, of the resistance encountered by boats moving on a canal with different velocities.

Without greatly increasing the propelling power of the passage boat, or materially endangering the abrasion of the banks of a canal, the speed of such boat may, it has now been demonstrated, be accelerated, from six to nine, ten, or even twelve miles an hour. The previously established ratio of the resistance to the velocity of the boat applying, it is now discovered, to slow and not to quick motion.

Should the views of the Chesapeake and Ohio Canal Company, meet the approbation of the several parties to their charter, and the western section of the canal be immediately begun, and conducted up the Monongahela and Yougheogany rivers, the portion of the canal between Pittsburg and Connelsville may be first executed, being a distance of less than sixty miles. A canal extending 58¾ miles above Pittsburg, having a depth of six feet water, with a breadth of sixty feet at its surface, and forty-two feet at bottom, overcoming an ascent of 146 feet 4 inches, by nineteen locks, has been computed, by two practical civil engineers, Messrs. Roberts and Cruger, of New York, to cost $1,718,633.

This estimate, includes no allowance for land rights or fencing; but it computes the entire lockage above mentioned at $1,000 the foot lift, the slope walls at more than one dollar the perch, and these two items, taken together, at more than a fourth of the entire sum above mentioned; while the heavier expenses of *excavation and embankment*, constituting, together, more than a moiety of the whole cost of the canal, are computed at more than the actual cost of the like items upon the part of the eastern section of the Chesapeake and Ohio canal already completed.

The average cost of more than three and a half millions of yards of embankment, exceeds eighteen cents, and of two millions of yards of excavation, twelve cents the cubic yard. On the western section of the great State canal of Pennsylvania, the reports of her canal commissioners show, that every description of work was done on cheaper terms, than on the eastern section. The preceding sum may, therefore, be considered as the maximum cost of so much of the western section of the Chesapeake and Ohio canal. With the liberal patronage of the United States, and such further aid as the State of Pennsylvania and individual enterprize within that commonwealth and elsewhere may afford, this sum will be, it is hoped, readily obtained.

Having completed one half of the portion of the canal between the western basis of the summit level and Pittsburg, there will remain but 27 miles of the other moiety of this distance to be provided for, in order to reach the mouth of Casselman's river, a point on the line of the canal in the vicinity of the Cumberland road. By the route of that road, this point is about 44 miles from Cumberland, the western termination of the eastern section of the Chesapeake and Ohio canal; by the route surveyed for the canal, about 67 miles; thirty-one of which lie between the mouth of Casselman's river and the western basin of the summit level.

It is apparent, therefore, that there will be several stages of this work where a pause may be made in its prosecution, without the loss of all benefit

from the portion of it which will have been completed. To this view, may be superadded, the highly important consideration, that the part which may, at any time, have been accomplished, will afford increased facilities for the more speedy and economical construction of the residue, and, in the interim, will contribute, by its profitable use, to the advancement of the public wealth and the general revenue of the company.

The memorialists having explained the motives which prompted the adoption of a plan of such enlarged dimensions for the eastern section of the canal, in order to obviate objections to the immediate commencement of the western section, return to the estimate of the probable cost of the former. With the view of shewing the competency of the funds, on which a reliance has been hitherto had for the completion of this section of the canal, they proceed to demonstrate, or render probable at least, the truth of their statement, as to the proportion which the cost of the part of this section now under contract, being that to the east of the "Point of Rocks," may be expected to bear to the greater portion extending to the west of that point, and east of Cumberland, along which their progress has been hitherto obstructed. For this purpose, they add to the statements of the last annual report, the following considerations:

Not only have the provisions hitherto consumed on the canal been transported a considerable distance, but nearly all the hydraulic lime for its costly aqueducts and its numerous locks and culverts, has been obtained from the New York canals, or from the Potomac quarries near Shepherdstown, twenty-five miles west of the "Point of Rocks," along a navigation so obstructed as sometimes to double its prime cost at the kilns on the river shore. Much of the stone for this masonry has been alike transported, and no small part of it by land, for great distances, and at great expense. Two dams, one of them exceeding half a mile in length, have been required across the widest part of the Potomac, to force the water of that river into the necessary feeders; and the expense of their construction, as well as of two considerable aqueducts, and of 28, of the 72 locks, required on the eastern section, are comprehended in the estimated or actual cost of the forty-eight miles of canal next below the "Point of Rocks."

Two other causes have powerfully contributed to swell the expense of the work already executed. The usual ill health, for a certain season of every year, of the valley of the Potomac, below the Kitoctin mountain; and the competition for labor on the canal, with two considerable works, the Baltimore and Ohio railroad and the Susquehanna and Juniata canal, of Pennsylvania; the former approaching very near, and the other not one hundred miles distant from the line of the Chesapeake and Ohio canal. Both causes have conspired for two years past to raise the wages of ordinary labor very far beyond the price anticipated when the estimates of the Washington convention were made. One of these causes will, in a great measure, cease, after the canal shall have ascended the Potomac to the healthy country above the "Point of Rocks;" and the final completion of the great State canal of Pennsylvania, will shortly limit the operations of the other.

Without taking into account the probable reduction of the prices of materials and subsistence, as well as of the wages of labor in the more fruitful country above the Kitoctin mountain, your memorialists are sustained, as well by experience, as by a comparison of the relative difficulties that were to be encountered by the canal, below and above the Blue Ridge, in computing the cost of the first sixty miles, between Georgetown and Harper's Ferry, at

much more than a third of the entire expense of the eastern section of 186½ miles.

For the cost of the twelve miles of this distance, immediately below Harper's Ferry, not already placed under contract, they rely on the frequently repeated estimates of practical engineers, corrected by a reference to the price of that part of the remaining 48 miles actually placed under contract, and at this time, either completed, or very nearly so. No part of these twelve miles nor of the 126 miles above them, presents obstacles, as difficult to surmount, as those which have been successfully encountered on the part of the eastern section already finished. The twelve miles next above the Kitoctin mountain, and below Harper's Ferry, comprehend but a single dam across the Potomac, at a place where the river is much narrower than either at Seneca or the Little Falls; and there are, in this space, but three lift locks to be added to the 28 below the "Point of Rocks."

Assuming, therefore, the present enlarged plan of the Chesapeake and Ohio canal to be the permanent basis of the dimensions of the entire eastern section, and computing the total cost of the section at near thrice the actual cost of the 60 miles next above Georgetown, and about five millions of dollars would be found to be the sum required to reach the town of Cumberland. It will probably reach five and a half millions. From this estimate, the work within and immediately above Georgetown is excluded, under a conviction that the mole and basin, at the mouth of Rock creek, will repay all the expenses incurred there, except on the locks. As these would have been required to descend to the tide, had the canal stopped above this town, they are comprehended in the preceding estimate.

For the mountain, or middle section, over which the Chesapeake and Ohio Canal Company are authorized to construct, either inclined planes and railways, or a continued canal, the memorialists have, however, never ceased to indulge the confident hope of assistance from that Government, which, created for the purposes of union and commerce, cannot be insensible to the claims of both these great interests upon the vigorous exercises of its powerful energies to remove every impediment to the easy intercourse of the Atlantic and western States through the centre of their common territory, and the seat of their common Government.

A plan for effecting this desirable object, has already received the approbation of the memorialists, and was sustained in an application to the President of the United States, on a recent occasion, by a large proportion of the House of Representatives. The doubts expressed by the Chief Magistrate of his power to employ the army on works of internal improvement, if still existing, it would, it is presumed, be in the power of Congress to remove in conformity with the past usage not only of other Governments, but with that of the United States, and the earnest recommendation of the Department of War in the second year of Mr. Monroe's administration. Should the direction be given to the labor of a part of the public force which that recommendation enforced, there will remain to be provided only the portion of the western section of the canal lying between the Alleghany mountain and Pittsburg; and, *for this portion*, an appeal is most respectfully addressed tothe enlightened patriotism of the representatives of the States and people of America.

Should the western section of the canal be retarded in its progress from Pittsburg towards Cumberland, by a suspension of it, for any considerable period, at any one of the points suggested above; should it, for example, be prosecuted no farther than the mouth of Casselman's river, it will, even

there, have arrived within a few miles of the national road, which already connects the Youghogany, at Smithfield, with the Potomac, at Cumberland. Through the application of the various mineral treasures, apart from the productions of the agriculture, and of the forests of the country between Smithfield and Pittsburg, a part of the resources for the completion of this section, would be speedily developed by the canal itself. It is, therefore, believed that, if a subscription be authorized, by Congress, for this purpose, to the extent of a single million, it will elicit a capital sufficient to defray the cost of all this central communication, except *its summit level*, and the descending planes or locks which are designed to connect it with the lines of continuous canal, stretching to the east and west, from the base of the Alleghany mountain.

To open, through this great barrier, from the Gulf of Mexico to the Chesapeake bay, an easy avenue of trade and intercourse to millions born and unborn, is, of itself, a work of such magnitude, as to require that it be commenced and prosecuted on a plan of *suitable dimensions* and with *adequate resources* for its speedy completion. It is for the Federal Government to sanction the one, since it is probable that it is, alone, competent to provide the other.

The memorialists would here close the appeal, which they have presumed to make, to the wisdom of Congress, in behalf of the western section of the canal, if they were not imperiously required, by a report of a former committee of the House of Representatives, to consider and to remove an objection to their whole enterprise.

To the memorials of the numerous citizens of Pennsylvania, who prayed for the aid of the General Government towards the construction of the western section of the Chesapeake and Ohio canal, the Committee on Internal Improvements, to whom these memorials were referred at the first session of the last Congress, replied, "that they duly appreciate the great and national importance of a communication between the western waters and the navigable waters of the Chesapeake bay, as is manifested in their report of the 19th of February, 1830, on the memorial of the Baltimore and Ohio Railroad Company."

The committee further stated, that, actuated by the same "desire of affording to the Government a satisfactory *experiment* upon which it can decide, whether a preference ought to be given to a canal or railroad, as the mode of conveyance over the mountains, they deem it inexpedient, at present, to make the appropriations, as the western communication, in the opinion of the committee, should correspond with the one leading over the mountains."

Such, the memorialists beg leave to remark, had not been the course of Pennsylvania, who is proceeding to connect, by a railroad of about 40 miles extent, across the Alleghany, her Conemaugh and Juniata canals; nor that of the Hudson and Delaware Canal Company, who combine a railway of 16 miles, overcoming an elevation and descent of 1768 feet, with a canal, exceeding in length one hundred miles, in order to reach the Lachawannock coal mines, from the North river; nor of the "Lehigh Coal and Navigation Company," who, for a similar purpose, have connected a canal and still-water navigation of 46 miles on the Lehigh, with a railroad of 9 miles, between Easton, on the Delaware, and Mauch Chunk. This last mentioned work overcomes, by its railway, a descent of more than 700 feet, and has, in a distance of 46 miles of mixed navigation, 47 lift locks, 6 guard locks, and

9 dams. The use, moreover, of its railway, long preceded, in point of time, the commencement of its canal.

The memorialists aver, that, at no period whatever, either before or since the prosecution of the great enterprise in which they are engaged, have they been unmindful of the progress of the science of internal improvement either in Europe or America.

While the proceedings of the founders of the rival enterprise of Baltimore disclosed the grounds of their preference of a communication with the west, by "*a direct railroad*," rather than by the course of the Chesapeake and Ohio canal, along the winding valley of the Potomac, the friends of the latter had no motive to deceive themselves or others. If such a communication were likely to supersede the use of the canal, while the former kept its avowed direction, and could not possibly interfere with the latter, the undersigned had not the *power* to arrest its progress, had they ever manifested or felt the disposition. They accordingly consulted all the information which the essays of scientific writers, or the actual experience of Europe or America could supply, in relation to the relative advantages of these different modes of transportation. They not only availed themselves of the reports of incorporated companies, of the matured judgment and counsels of practical civil engineers, but carefully inspected all the materials for a correct decision upon this interesting subject, which the advocates of the "*direct railroad*, from Baltimore to the Ohio," could, themselves, supply.

These inquiries ended in a conviction which remains to this day unshaken, that such a canal as they have planned and partly executed, will furnish a much cheaper mode of transporting the heavy products of American industry, than any railroad whatever; and especially, than one, the cost of which shall not very greatly exceed that of the Chesapeake and Ohio canal. In this opinion, they are fortified by all the recent information which they have been able to obtain from Europe or in America, as well as by the continued practice of various incorporated companies, and States of this Union. Let it be remarked, that not a single canal in Europe or America has yet been converted into a railroad; that, from those very railways in America, on which reliance was early had to establish the superior advantages of railroads over canals, abundant testimony has been obtained to disprove the truth of this position, while the reference, so often repeated, to the experiment now in progress between Liverpool, the chief western port of England, and Manchester, her greatest inland manufacturing town, through her richest and most extensive mineral and manufacturing district, if it manifests any thing at all conclusive, on this subject, demonstrates the utter unfitness of this species of communication to the very uneven as well as unimproved surface of the country, between the tide of the Atlantic and the Ohio, and to the present condition of the wealth, arts, and population of the United States.

The construction of this road, about 30 miles long, has been the labor of six years, attended with the cost of about $140,000 a mile. Its highest elevation above tide water is 140 feet; its patrons originally proposed by it, to reduce the cost of transportation between Liverpool and Manchester, from 15 shillings sterling a ton, to 10 shillings, or eight cents a ton per mile—a price which, when compared with the average cost of carriage on the canals of the United States, exceeds the latter in the proportion of three to one. Persons are hired along the margin of this road to sweep the dust from the rails, to give signals of accidents, and, after all, a report of its proprietors ac-

knowledges that the wear and tear, both of the carriages and road, surpassed greatly their early anticipation.

In conformity with the sober and deliberate conclusions of experience, from known facts, is not only the past, but the still continued practice, as has been intimated, of the most enlightened States of this Union, in all cases, where canals are practicable, and no narrow interests, or local jealousies have arisen to obstruct their execution. New York, Pennsylvania, Connecticut, and Ohio, may be confidently cited to sustain this authoritative appeal to experience.

A report on the long contemplated and much desired union of the waters of the Delaware and the Raritan, adds to these authorities the weight of the commonwealth of New Jersey, whose proceedings in connecting the waters of her rivers, have been marked by so much prudence and circumspection. In the language of the committee, to whom was referred the subject of the Delaware and Raritan canals, addressed to the House of Assembly of that State, in January, 1829, in answer to the suggestion that "there is time enough to profit by additional experience," your memorialists admit that "science is daily improving," but, like the authors of that able report, they are not willing, and they trust, that they shall not be required, to delay a great national enterprise "till time ceases to shed new light," and "science pauses in her career." "*Time* is money," and "time stops for no man," are maxims applying with peculiar force to all such enterprises. The Chesapeake and Ohio canal, the long contemplated object of unceasing solicitude and unwearied labor, can be completed, in five, as readily as in fifty years. On the other hand, the *experiments* of the relative utility of railroads and canals, which have already occupied more than one-fourth of a century, are still, it would seem, regarded as inconclusive. Many years would yet be required, and much capital of necessity be wasted, were the particular experiment instituted, which the Committee on Internal Improvements of the last Congress proposed, before it would be definitely settled, by the comparative expense, for a series of years, of the annual repairs of the Baltimore and Ohio railroad, and of the Chesapeake and Ohio canal, to say nothing of their original cost, and their annual receipts. As the one deteriorated, it might be found that the other improved, from use. The very question, so often triumphantly urged on one side upon the public notice, touching the relative speed of transportation, along two such lines of communication, could be fairly tested, only *by the long continued use of both*, with equal amounts of tonnage. That railroads should be constructed in Great Britain, where canals have so long afforded a monopoly of enormous profits, and have, in fact, appropriated to themselves almost every stream capable of being diverted from its natural channel, to their support, furnishes no very conclusive argument in favor of their superiority in America, a country in which the navigation of so many considerable rivers yet remains to be improved. Nor is the advance of the prices of railroad stock, in England, to fifty, or even to one hundred per cent. above par, at all more conclusive on this point, since, in the very same money market, canal stocks are still, in some cases, a hundred, in others a thousand, and even two thousand per cent., above par.

The time, though remote, may, possibly will, arrive in America, when *mere speed of transportation* will warrant the very heavy cost of constructing railways of such graduation, and of so many different tracks, as to admit of various velocities, for persons and property, moving at the same

time in opposite directions; and of the substitution, on each o those tracks, of locomotive, or even of stationary steam engines, of various powers, for animal labor. When this period does arrive, it will be time to legislate for it; until then, it is demonstrable that canals cannot be profitably turned into railroads.

Extracts from note E. of the appendix in Doc. No. 18, *designed for the same purpose as the preceding.*

From the character of the canal already completed below the Point of Rocks, and especially of that part of it between the 11th and 33d sections, as well as in the vicinity of Georgetown, it must now be apparent that the early assurance given to the public, that the entire eastern section could be finished in three years from its commencement, might have been realized, provided no legal obstruction had impeded its progress, and adequate funds could have been provided.

It is as confidently believed, that nothing more is necessary, in order to manifest the superiority of the Chesapeake and Ohio canal, to any other mode of transportation applicable to the valley of the Potomac, than to bring it into actual use above the obstructions of that river, at Harper's Ferry.

The annexed tables, presenting an exhibit of the cost of each section of the canal, from the tide-lock in the mole at Washington, to the Point of Rocks, and of the estimated cost of the twelve miles above that point, which remain to be constructed, in order to reach the mouth of the Shenandoah, will show that the work above Georgetown, done, and to be done, on the first sixty miles of the canal, will cost about 30,000 dollars a mile, exclusive of contingencies. In one of those tables, a comparison is instituted between the actual cost of this work and the estimate made of it by the United States' engineers, who terminated their calculations at Market street in Georgetown; where they proposed to form a basin, and to which, therefore, this comparative view is made to descend.

For the sake of any inference which may be drawn from this comparison, it should not be forgotten, that the breadth of the canal, at the water-line, was designed, by the United States' engineers, to be 48 feet, its bottom 33 feet, and its depth 5 feet; of which, they say, "this transverse section is to be modified, where local circumstances require it, and more especially, in the cases of deep cutting, steep side-cutting, embanking, and also where the canal is supported by walls. The depth of 5 feet has been preserved throughout the line, but the breadth has often been much lessened."

The actual canal, on the contrary, is 60 feet wide at the water-line, 42 at bottom, and 6 feet deep, and has been reduced in breadth, below these dimensions, though all the above contingencies frequently occur in its course, for less than a single mile altogether, of the 48, now very nearly completed. It is, indeed, much more frequently enlarged than reduced; it is never less than 6 feet deep; and where its breadth, as for the four miles next above Georgetown, is less than 80 feet, its depth is extended to seven feet below the top water line, forming a cross-section, throughout, of about 420 feet below water.

To compare these two canals together, the surface of their respective towpaths and berm-banks being, with the same inside slope, two feet above

their water-line, it should be considered, that their entire cross sections, or mean breadth, multiplied into their depth, are to each other as 432 to 304.6; and the cross sections of their water-prisms, where the larger is only 6 feet deep, as 306 to 202.5.

The breadth of the tow-path of the larger canal is, also, constructed three feet wider than that required by the estimate of the smaller; the culverts of the larger are never reduced to a less length, than a canal of 60 feet breadth requires: all of them are constructed, where practicable, so high, as to enable a laborer to walk erect through them, and several are enlarged to dimensions which will permit loaded wagons, and all other conveyances for persons or commodities, to pass under them. The locks are four feet shorter than those recommended by the United States' engineers; but they are, at the same time, a foot wider and a foot deeper; and they are all constructed of cut-stone masonry, laid in hydraulic lime, without any use of common lime, except in the backing of a few of them, where, in the facing, the English Roman cement was freely used. Grubbing will be found not to have been included in the estimate of the United States' engineers, nor the incidental expenses of excavating and embanking the locks, constructing houses for lock-keepers, nor the necessary improvements developed, on opening the canal, by the admission of water. These items in the table swell the cost of the actual canal 110,000 dollars; on the other hand, the cost of but one permanent bridge, and an allowance of 4,400 dollars for that and the bridges above the Market house in Georgetown, is included in the cost of the part of this canal above that town. The cost of fencing, estimated by the United States' engineers at 54,900 dollars, although not included in the actual cost of the work, is comprehended, in the indemnities awarded by juries, and the compensation voluntarily agreed on, or the prices paid, for the land purchased of the adjacent proprietors in behalf of the company, between the canal and river.

The United States' engineers considered their estimate, moreover, as possibly covering the usual allowance of five or ten per cent. for unforseen contingencies—some of which are comprehended in the cost of this part of the actual canal, and others of which have been already noticed in this report.

As might have been expected from the enlarged dimensions of the area and embankments of the new canal, the quantities of the work *estimated*, and *done*, essentially and greatly vary. The cubic yards of embankment estimated by the United States' engineers, for the canal below Harper's Ferry, amounting to 748,580 yards, and, if the puddling be added, which does not seem, from the estimate of its cost, to have been designed to affect the quantity of the embankment, to 1,056,710 cubic yards; while the actual embankment, including the puddling, as the calculation requires, added to the estimated quantity of that remaining to be done, amounts to 1,753,571, exclusive of the embankments around the locks, which are separately charged in account, and amount to no inconsiderable quantity.

The excavation and the walling are, in quantity, nearly the same, though differing in cost near $740,000. The walling of the actual canal exceeds that of the estimated, less than 14,000 cubic yards, while the computed cost of the latter surpasses the actual cost of the former near $500,000. Ninety-six culverts are provided for in the estimate; eighty-one in the canal; but the disproportion in breadth, between the aqueducts, arises from the different denominations given to them: the aggregate cost of both, on the two canals, varying less than 4,000 dollars, notwithstanding the greater breadth of those on the larger canal, and the peculiar difficulties attending the con-

struction of the aqueduct across the Monocacy, which surpasses in the size of its arches, and exceeds in length, as does that at Seneca, the dimensions for which an estimate is given by the United States' engineers.

The total difference, presented by this table, of the cost of these two canals, is, subject to the preceding explanations, 677,184 dollars, on an expenditure actual and estimated, of 1,848,941 dollars; and this, notwithstanding the great enlargement of the area and embankments of the cheaper canal.*

These facts and comparisons are presented to the stockholders, and to the public, in no spirit of triumph over the very eminent, disinterested, and highly honorable engineers, by whom the first estimate of this work was made; it is well known, and gratefully acknowledged, with no unfriendly feeling towards its future progress. This progress, indeed, their very errors are calculated to promote: for, having accustomed the public mind to so large an estimate of this work, they have laid the foundation of its ultimate success, by the contentment with its actual cost and plan, and, it is believed, with its construction also, which, whatever dissatisfaction may elsewhere prevail, must finally pervade its early and steady patrons, as well as the subscribers to its stock.

But this comparison will disprove, and such is one of its purposes, the allegation, recently repeated, after reiterated contradictions, that the actual cost of the Chesapeake and Ohio canal had not fallen short of that estimate, by which, the construction of its eastern section of 186 miles, ending at Cumberland, was made to reach $8,177,081 05, and its total cost to Pittsburg $22,375,427 69.

Lest advantage shall be supposed to have been taken in the comparison just closed, either of the easier ground, along the bottoms above Seneca and the Monocacy, or of the mere estimate of the work, not, as yet, begun, between the Point of Rocks and Harper's Ferry, the board especially invite the public attention to the portion of the canal which is not only completed, but has now been *in actual use* for several months; and, of this, to the tenth subdivision, which extends from the head of the Great Falls, to tide-water, at the old locks below the Little Falls.

The accompanying table, distinguishing the several subdivisions of the canal, from the 7th, beginning at Harper's Ferry, to the 11th, ending at the Market house in Georgetown, gives to the 10th a length of 11 miles 1023 yards in the estimate by the United States' engineers, and 10 miles 1005 yards in the actual canal between the same termini; a difference occasioned by a change of the location for about three milles and a half of the way. The difference of cost, after deducting from the estimate the computed expense of the locks transferred from the 10th to the 11th section, on this subdivision of the canal, largely exceeds 200,000 dollars. While the actual excavation and embankment, together, of the new canal, surpass, in quantity, the estimated quantity of earth and rock 124,000 cubic yards, the walling 27,463 perches, the actual cost of the three items is less, on the larger canal, than in the estimate for the smaller, by 265,985 dollars, although the embankment of the larger subdivision exceeds that of the smaller, in cost 56,747 dollars, and, in quantity, including the earth puddled, in the ratio of very near two to one. If the quantity of puddling should not be added to the quantity of the earth estimated in this ratio, which is believed to be correct, then this ratio will be as 529,933 to 150,860, or will considerably exceed 3 to 1.

* The real expenditure has been found to exceed the estimated, so as to reduce this sum to about $500,000.

To guard against the supposition that this part of the canal passes over easy ground, here follows the description of it by the United States' engineers, in their own language, to be seen in the 49th page of a congressional document.

"*Subdivision* 10*th*. From the head of the Great Falls to tide, below the Little Falls:

Distance, 11¾ miles—descent, 173 feet—22 looks.
From Cumberland, 183½ 578 74

"The breaking of the Potomac through the granite ridge, at the Great Falls, presents, at first sight, difficulties of the greatest magnitude. The river gradually narrows its channel as it approaches its perpendicular pitch. At this point, and a little below, the width does not exceed one hundred yards, at a moderate stage of the stream. Here the perpendicular rock, 60 or 70 feet high, forming the banks, the deep water at their foot, the violence and great rise of the freshets, render truly appalling the idea of supporting a canal along this pass by means of walls. Most happily, there is no necessity for such a plan; a ravine, or rather two ravines, which can be rendered continuous by comparatively little labor, extend for the whole distance between what is termed Bear island and the high bluffs forming the Maryland shore

"This fortunate circumstance will not only enable to make the canal here at much less expense than through the pass of the stream, but it will also procure to the work a security which neither ingenuity nor expense could afford on the other alternative.

"Below the Great Falls, the ground, with the exception of some portions of easy execution, is generally difficult, requiring a large extent of walling and of steep side cutting, for about seven miles: that is to say, as far down as the head of the actual canal round the Little Falls."

Although the location of this line was improved by subsequent examination, yet, on no canal in America, and on very few, if any, in the world, will there be found, and certainly on no part of the Chesapeake and Ohio canal, do there remain to be encountered, obstacles more appalling, than have been here overcome: so they were regarded by the distinguished foreign engineer then at the head of the United States' Board of Internal Improvement, whose language has been quoted above.

In the compass of eleven miles, along precipices of granite, bounding a river which bore last winter, on its bosom, ice and snow, elevated for several miles thirty feet above its ordinary height, a canal was to be constructed, to overcome a rise of 128 feet, being more than eleven feet in each mile. For a part of this way, a practicable pathway could not be formed but at great cost; and many hundred acres of huge and craggy rocks, piled on each other, chilled the enterprise which attempted to subdue them. Earth was to be derived from remote distances to construct embankments, and the embankments to precede the transportation of the stone and other materials required for the construction of six of the sixteen locks. The beds of not a few of these were either to be sunk in the uneven rock, or to be lifted up high above it, and sustained by lateral walls and embankments. It is not wonderful that the United States' engineers, who first traversed, described, and estimated the route for this canal, along the north bank of the Potomac, around the Great Falls, should have estimated its cost at near 80,000 dollars a mile, supposing their canal to be forty-eight feet wide at the surface of the water, and five feet deep except where "*reduced considerably*," as often as peculiar difficulties, which here occurred at every step of their way, required that breadth to be diminished.

A reproof is given to those persevering misrepresentations, which swell the actual to very near the estimated cost of this work, by the spectacle of a canal, in use, between the same termini on the Potomac, completed at a cost of 20,000 dollars a mile less than that estimate; constructed, too, with a breadth exceeding every where in that distance, forty-eight feet, often more and seldom less than sixty feet, and a depth never short of six feet; having beneath it, numerous culverts, some large enough to serve as viaducts to every species of conveyance; with sixteen cut stone locks, laid in hydraulic lime, seven of which are of hard granite blocks, and nine of free stone, transported from 10 to 60 miles, by water and land; while the canal itself is, for several miles of the eleven, lined along one or both of its inner slopes with a neat stone pavement, supported on the outside by massy walls, in some places sixty feet high, to guard it from abrasion, and has, moreover, included in its cost, more than 22,000 dollars expended on its improvement, exclusive of its repairs, since the opening of its navigation.

Several benefits would accrue to the Chesapeake and Ohio Canal Company from a close analysis of the causes of the actual, compared with the estimated, cost of this enlarged and difficult line of canal. Among them, would be a general conviction, that too much has not been expended in repeated surveys, by eminent practical civil engineers, preparatory to its final location; nor if the number, variety, and quality of its works be regarded, in multiplying, to the necessary extent, the corps of engineers, by whom its actual construction was to be vigilantly and constantly watched.

There can be no question but that the part of the canal already completed exceeds in difficulty, and will be found to have surpassed in cost, that part of the eastern section which remains to be executed.

Between Harper's Ferry and the basin of Washington and Georgetown, 31 of the 72 lift-locks of this section occur; so that 248 feet of the entire elevation from the tide to Cumberland, will have been surmounted in the first 60 miles of the 186 which constitute the entire eastern section; making, if this proportion be examined, a difference of more than $3,000 per mile, for lockage only, in favor of the part of the canal above the Shenandoah.

In the single material of hydraulic lime, required for every species of masonry exposed to the action of water, and absolutely necessary in the construction of durable locks of stone, not less than the farther saving of 500 dollars will be effected on the cost of each lock, by the reduced price of transportation.

Stone, if not more abundant, will be found more conveniently distributed, above the Blue Ridge, than below. Outward protection walls will be often required, and, for considerable distances, above, as below, but no walls or embankments, exceeding in height one-half of the elevation of those on 12th, 15th, and 18th sections of the work already completed. Much narrower dams across the river, as noticed in the former report, will be necessary to fill the feeders at and above Harper's Ferry. Above all, setting down at nothing the gain of experience, the general health of the valley of the Potomac, and the abundant supply of provisions and accommodation, which that circumstance, as well as the superior fertility of the country, promises to the laborer above the Point of Rocks, will reduce the price of every species of work after passing that point.

If the company shall be permitted, by the courts of Maryland, to conduct their canal along her shore, on the ground so often surveyed for its use, no aqueduct like that of seven arches of fifty-four feet span, across the Mono-

cacy, will occur to swell the cost of the masonry above that river. All the aqueducts and culverts of the 140 miles above will probably not exceed, in cost, those of the 46 miles below the Point of Rocks.

Twenty-five thousand dollars a mile is, therefore, considered an ample estimate of the part of the eastern section, in length 126 miles, above Harper's Ferry. This part of the canal will therefore, require for its construction 3,150,000 dollars, which, added to the cost of that between Harper's Ferry and Georgetown, will produce very near the former estimate of 5,000,000 dollars, leaving, as that estimate did, the works in and above that town, to be paid for by the peculiar uses of which they are susceptible, in the manner heretofore proposed.

The compass of this already extended report refuses admittance, into its text, of all the very interesting intelligence to be derived from the late work of Mr. William Fairbairn, addressed to Thomas Grahame, esq. of Glasgow, from which the following extracts are made:

They prove, beyond the possibility of doubt, that a velocity of 15 miles an hour has been attained on the Forth and Clyde canal, which, although ten feet deep, is, in width, but three feet broader than the Chesapeake and Ohio canal; that, on the Ardrossan canal, one of the narrowest in Scotland, a velocity of 12 miles per hour has been attained, and that "eight persons and the steersman of a boat accomplished a distance of two miles, with one horse, in ten minutes, without any surge, or agitation of the water, injurious to the banks."

The summary of the results from the first experiments on the Forth and Clyde canal, embraced three objects, worthy of particular notice, as this author very justly affirms: "First, the ease with which boats were brought up, or stopped, when moving at a high rate of velocity; secondly, the little additional labor, in drawing, occasioned to the horse, when drawing the boat at this high rate, as compared with a low rate of velocity; and thirdly, the apparent diminution of the surge, or agitation in the water, at a high rate of velocity.

Since these experiments, "a boat has been regularly plying between Glasgow, Paisley, and Johnston, on the Ardrossan canal," and carrying "from forty to fifty passengers, at the rate of from nine to ten miles an hour."

Other experiments have been made, on the Monkland, the Union, and the Forth and Clyde canals of Scotland, to two of which, made on the last of these canals, as far back as the 7th and 8th of July, 1830, the attention of the stockholders is particularly invited, as they show that the velocity of the passage-boats on the Chesapeake and Ohio canal, will not encounter peculiar or inseparable obstructions from its numerous locks. It has, as yet, but one permanent bridge above Georgetown, in a distance of 48 miles, and that is not only very elevated, but designed to be provided with a suitable draw.

"On Wednesday, the 7th of July, the Swift, a boat 60 feet long and 8 feet 6 inches broad, twin built, and fitted to carry from 50 to 60 passengers, started from Port Dundas, at 16 minutes past nine in the morning, having on board 33 passengers (all men) and their baggage. Proceeding through the Forth, and Clyde, and Union canals, she reached Edinburgh at 29 minutes past four in the afternoon. She thus made a voyage of 56 miles and a half in the space of 7 hours and 14 minutes. In the course of this voyage, she passed through 15 locks, 18 draw-bridges, a tunnel of 750 yards long, and over three long narrow aqueducts, and under 60 common bridges,

which carry roads over the Union canal. Her average rate of speed, during the voyage, was nearly eight miles per hour, including every stoppage."

"On the following day, Thursday, the 8th of July, the SWIFT started from Edinburgh, 22 minutes past nine in the morning, and returning by the same route, with 33 passengers (all men,) and luggage, she reached Glasgow precisely at 4 o'clock in the afternoon—that is, in 6 hours 38 minutes: going, thus, at the rate of nearly nine miles per hour." "On both days the weather was most unfavorable, from much rain, and a strong gale of wind directly in her face, having been from the east on Wednesday, and from the west on Thursday." "When free from the locks, tunnel, and other impediments, the speed at which she proceeded varied from 6 to 12 miles an hour; and the extraordinary results of the previous experiments made on the Paisley canal, and Forth and Clyde canal, were again completely verified and ascertained during her progress through 113 miles of canal navigation. For it appeared that when she moved through the water at the rate of 6 or 7 miles an hour, there was a great swell or wave constantly in her front, and she was followed by a strong surge or wave bearing against the bank of the canal. At these times, the hauling rope was tight, and the horses appeared to be distressed. But, as the speed was increased, the wave, or swelling of water in her front, sunk down; and when the speed came to be about nine miles an hour, the swell entirely disappeared; the waters in front became smooth and level; the hauling rope slackened, and the horses seemed easy; and little or no surge was to be seen on the banks behind the vessel."

On these experiments, the following comment is made by the same writer: "There appears, therefore, no reason to fear that the banks of canals can ever be hurt by increasing the speed of boats to the utmost attainable height; and measures are in progress for increasing the speed of passage-boats on the Forth and Clyde canal, and the Union canal; or, at least, of keeping it, during the whole voyage between Glasgow and Edinburgh, to the highest rate which has been already realized, and thus reducing the time consumed in the voyage to five hours."

To these experiments, Mr. Fairbairn has added many others, which are referred to in the text, and more minutely described in the appendix of his very interesting work; and from them he deduces results confounding all the established theories, "that the resistance to a body drawn along a line of water confined within the banks of a canal, did not appear to increase in the ratio laid down in theory; and that, while at a low rate of velocity, viz. at and under six miles an hour, the resistance to the progress of the boat, on a broad line of water, was considerably less than on a narrower line; on the contrary, at a high rate of velocity, say above ten miles an hour, the forces necessary to the propulsion of the boat, on a broad and narrow line of water, appeared to be the same, if the advantage was not rather in favor of the narrow line."

From these observations, he was induced "to recommend, and the Forth and Clyde Canal Company to agree to build a light twin iron steam passage-boat, to ply between Glasgow and Edinburgh," which, at the date of his publication, he was preparing to launch. "Her length is to be 68 feet, her breadth of beam 11½ feet, her steam-engine to be of ten horse power, the diameter of her paddle-wheel 9 feet," "and its motion calculated to give from 50 to 60 strokes in the minute; her whole weight 7 tons 16 cwt. and

her draught of water 16 inches. She will accommodate from 100 to 150 passengers; her anticipated velocity will be from nine to ten miles an hour, and the cost to the canal company, for the conveyance of a passenger between Edinburgh and Glasgow, 56 miles, will not much exceed two pence; which," Mr. Fairbrain adds, "is not a fifteenth of the expense of the conveyance of the same person, at the same rate, supposing it attainable and maintainable, by horses."

Mr. Fairbairn says, "that however much I was persuaded that steam power was the cheapest for high velocities, and also for propelling vessels in canals, where the trade was regular, I was not, till lately, prepared to consider a steamboat, on a canal, as the cheapest for the conveyance of goods, where the trade was irregular, and where the boat had not only to contain a cargo, but, at the same time, to carry her own engine, and all the conveniencies necessary for the application of machinery."

But he proceeds—"Mr. Grahame has lately put into my hands a letter on this subject, addressed to a shipping company, carrying goods along a line of canal 56 miles in length; the calculations contained in that communication are given in the appendix, and seem to be decisive in favor of steam power. The company to which this letter is addressed, have to pay for a quantity of horse power sufficient to deliver forty tons of goods,at each extremity of this line of 56 miles, every day in the year, besides a spare power employed chiefly in one particular branch of their trade.

"The sum they pay for each delivery is one guinea, each way, or at a rate of about one-ninth of a penny per ton per mile, for the trackage of the goods conveyed, the company in question supplying the tracking lines, but, with this addition, the charge fortrackage is not increased to one-eight of a penny per ton per mile.

"This," says Mr. Fairbairn, "is certainly a small sum whereon to effect a saving by a change of power; but, nevertheless, it appears (from Mr. Grahame's and my own calculations) that not only such saving may be effected, but an additional saving of a large portion of time can be made, by the change from horse to steam power."

"The calculations there referred to, make it quite unnecessary," adds the writer, "to say any thing on the subject of *steam power* as a substitute for trackage, on canals. If *it* be so much cheaper than horses, in the expensive shape of a moving and carrying power *united in the same boat*, what advantages may not all canals derive from its introduction, in the cheap form of a tug boat, in place of horses?"

In his appendix, the author adds—"I am the more convinced of the efficacy of steam trackage above all others, from the circumstance that the train of boats intended to be towed, would follow in each other's wake; as the eddy formed by the leading vessel materially lessens the resistance opposed to the succeeding boats." "The small amount of power required to a tow vessel, was remarked by Mr. Grahame, in his account of the voyage of the Cyclops, from Alloa to Port Dundas." He states that "when we brought her into the canal, we attached her to the passage boat, and she drew her along the canal two miles—one mile in fourteen, and the other in fifteen minutes. We then detached her from the passage-boat, and did two other miles, but could not save by this decrease of labor, more than a minute, or a minute and a few seconds in each mile. One thing is very evident," says Mr. Fairbairn, "that the introduction of steam instead of animal power, would dispense with the annual repairs and maintenance of the horse paths; the com-

plaints and delays arising from drivers, horses, &c. would be avoided, and many contingent expenses saved by the introduction of this never-failing and very effective agent as a moving power for the towage of boats on canals."

The great importance of the facts and views supplied by the work of Mr. Fairbairn, of which, it is believed, but very few copies have reached the United States, will constitute, it is confidently hoped, a sufficient apology for the copious extracts here made from it. If this work shall serve but to invite the public attention to the erroneous but prevalent opinion, that no further improvement can be made in inland navigation, by canals, because, sustained by monopoly, they have been so long stationary, this notice of Mr. Fairbairn's work cannot prove useless, since experience, as he has incontestibly shown, is exploding the doctrines on this subject, hitherto sustained, without exception from any quarter, by the exclusive advocates of railroads.

But the board do not feel that they would discharge their duty to their immediate constituents, or to the public, who are interested in the completion of the great highway which they have long been constructing, if they did not proceed one or two steps farther in this investigation.

In the course of proceeding to which a committee of the House of Delegates of Maryland resorted, last winter, letters were cotemporaneously addressed by the chairman of the committee, to the Baltimore and Ohio Railroad, and the Chesapeake and Ohio Canal Companies, inquiring, among other topics, for which the undersigned beg leave to refer to the letter itself, "into the relative expense, benefits, and facilities of constructing railroads and canals, with a view of ascertaining to which of these means the funds of the State can be most beneficially applied." Their own answer to this letter, through the official communication of the President of the board, will be seen in an accompanying printed pamphlet.

That of the Baltimore and Ohio Railroad Company was made, in part, through their chief engineer; and never having been seen by this board, nor the report, of which it made a part, till since the adjournment of the Legislature of Maryland, the present affords the first occasion for referring to some of its very curious contents.

Reserving for a separate notice, the other subjects of the report, and especially those of a personal nature, *seemingly* designed, and certainly calculated, to reflect on the proceedings of this board, they invite the attention of the stockholders of the company, and of the public, to the very singular use, among others, which the chief engineer of the Railroad Company, has made of the joint survey for a railroad and canal, along the difficult passes, four in number, somewhat less than two miles in extent, in a distance of twelve, between the Point of Rocks and Harper's Ferry, *in order to establish the superior economy of railroads to canals.*

The writer premises, "that, as a canal and a railroad cannot be constructed between any two points on the same identical route, the evidence of their comparative expense, on a given line, must consequently be that of an estimate for each, or by an approximate conclusion drawn from analogy;" "I know," he adds, "of but one route on which careful estimates have been made at the same time, both for a canal and a railroad. The *route* here alluded to, is along the Potomac river, from the Point of Rocks to Harper's Ferry, or at least *so much of that route* as was included in the narrow passes:" as was included, he should have added, in $1\frac{7}{8}$ mile, out of a distance of 12, along which no estimate whatever was made for a railroad of any description. The survey of that engineer having been exclusively di-

rected to those narrow passes, as the only lines of expected interference between the canal and railroad.

But his conclusion far outruns his premises. "From these estimates, therefore, added to the estimates for the railroad, an average price for the laying of three tracks of railway, on the graduated surface, so to be prepared, we arrive at results which will give the comparative probable expense of both the canal and railroad. The canal was assumed to be of such dimensions, that, with a depth of water of six feet, its cross section should contain an arena" [supposed to be intended for area] "of 306 square feet. The breadth of graduation for the railroad was to be 30 feet." Hence, as the canal was to cost, at these narrow passes, "at the rate of $79,036 per mile, and the railroad constructed on wooden sills, but $38,294 per mile, or after adding $1,000 or 1,500 per mile for stone sills, something less than $40,000," the writer concludes, "on the *whole, since the estimates for the canal do not include any lockage, although* 40 *feet elevation is to be overcome between the Point of Rocks and Harper's Ferry, nor* $5,000 *a mile*," at which he is pleased to estimate the cost of lining the interior banks of the canal with stone; "*a precaution*," he says, "*without which, the experience of the Erie canal shows that no such work can be considered as finished*," "that the ratio of the probable expense of a railroad and canal will, on the ground here estimated, be as two for the canal, to one for the railroad."

So singular does his own conclusion appear to himself, that, to guard against criticism, he acknowledges in his fourth commentary on these comparative estimates, that, "he has not seen the last estimates for the canal, on the *intermediate grounds*, (more than ten miles of the twelve,) and therefore cannot institute *so strict a comparison* with regard to them;" but he makes a broad assertion, that "*in the most favorable ground along the river bottom lands*, the expense of the canal will exceed that of the railroad, from 25 to 50 per cent."

Whether this reasoning proved satisfactory to the President of the Baltimore and Ohio Railroad Company, to whom it was addressed, and by whom it was transmitted, without comment, to the committee of the House of Delegates of Maryland, does not further appear, any more than does the effect it may have produced on the committee or on the House. But such reasoning is so extraordinary in itself, and contradictory of known facts, part of which are supplied by the author himself, that it is difficult to reconcile it to his high reputation for candor.

The spaces along which the four short lines of canal and railroad were expected to come in collision, the longest of which is in length but 3,052 feet, and the shortest 1,126, are four difficult projecting cliffs of rocks, hemming in the current of the Potomac, at the bases of the mountains and ridges, by which it descends, from the Blue Ridge, through the Kitoctin mountain. The railroad was to be bedded on these rocks, for a space of 30 feet only, in breadth. The canal, having a cross section of 306 feet; and a depth of 6 only, could not have a breadth, at the surface, of less than 51 feet; and, adding 3 feet, for the stretch of the inner slope of earth, next the river, 12 for the breadth of its tow-path, and 20 for the horizontal stretch of the outward slope; supposing that the tow-path bank is not any higher, above its base, (here in the river,) which is improbable, and that the angle of the slope is as steep as 45°, which would be inexpedient, we have a space, constructed, partly on rock and partly in water, of the breadth of 86 feet, compared with one of 30 feet; and the canal, in this space, charged with all the attendant ex-

penses of outside walling, to guard against abrasion from the river, puddling within its banks in order to retain the water admitted into it, and, as the calculator provides, $5,000 a mile also, for paving within, although one of its sides must be of rock.

Had the writer inquired for the estimates of the part of this canal along the "intermediate grounds," he would have found that the working estimate, prepared to regulate the acceptance or rejection of proposals for its construction, does not extend the cost of the twelve miles, after including not only its lockage, but the expense of a substantial dam across the river, immediately below Harper's Ferry, beyond $250,000; a sum, less than that, which he admits the railroad will cost, within the same distance.* For, putting down the cost of the road provided for, on his own estimate, at $39,794 a mile, and its length, at his measurement, of 11,134 feet, its tracks, as he proposes, at three in number, to be laid on stone sills, as he suggests, though on the principle of perfection, which he applies to canals, he ought to provide, at least, a fourth track, for the cars to pass each other with various velocities, which would add to this estimate at least $13,233 more, for this track; and the further cost of graduation, and their results, in order to reach Harper's Ferry, for the 3 tracks, at $6,500 each, on a line of 9 miles, and 4,706 feet, *for the rails alone*, $192,880, which, added to the cost of 11,134 feet, computed, by himself, at $39,794 a mile, furnishes an aggregate of $276,794 without any allowance whatever for graduating the foundation of the rails for a distance of 9 miles and 4,706 feet, or for a single perch of masonry, for culverts, viaducts, or side drains of any description; an aggregate exceeding the working estimate for the canal, along the same line, by the sum of $26,794; and if, but a moderate allowance be made for the graduation, including the masonry of the railroad, by a sum, not much short of one hundred thousand dollars.

It has been acknowledged that these items, exclusive of the rail tracks on the first 7 miles of this road, leading out of Baltimore, cost $438,775 85, exclusive of all contingencies, being $62,654 80 per mile; and allowing for three tracks with stone sills, make up a sum, exceeding $80,000 a mile, exclusive of contingencies. These, even on this part of this road, cannot appear inconsiderable when reference is had to the report of the President and Directors, from which the above facts are obtained, wherein "sixty-one thousand one hundred and seventy-seven dollars twenty-five cents are charged to expenses incurred in surveys and locations, including the pay of engineers and their assistants; six thousand eight hundred and sixty-five dollars thirty-two cents for law expenses, fees of counsel, and chancery expenses; and sixty-six thousand nine hundred and eighty-eight dollars sixty-two cents for cost of machinery, for the purpose of construction of the railroad, of transportation and weighing, including the purchase of patent rights, and moving power, contingencies, expenses of widening the cuts, and embankments, and *perfecting the graduation* at the time of laying the rails, releases of the right of way, discounts, expenses of opening the books, &c." How much of the $66,988 62 should be charged to the first seven miles of the road is not stated, though a part of it would seem to belong to the graduation, or the "*perfecting of the graduation*, prior to the laying of the rails," it being the part of this road whereon the rails were first laid; nothing is added for the improvements subsequent to opening the road.

*The 12 miles have recently been placed under actual contract, for $324,000; including the cost of land rights and fencing, and five per cent. for contingencies.

It would, it is obvious, be unfair to charge the proposed railway, between Harper's Ferry and the Point of Rocks, with the maximum cost of the graduation, on the most expensive part of the route of this road, but it would be equally correct, with the course actually pursued, by the chief engineer of this company, in ascertaining the relative costs of canals and railroads, by referring to the construction of short pieces of canals and railways, under, or upon precipices of granite, and in the bottoms, or along the rocky margin of rapid rivers.

Much more incorrect, however, is the general assertion of this engineer, that, "on the most favorable ground," for a canal, "its cost will exceed by 50 or 25 per cent. that of a railway," (of course such as he has been describing,) of three tracks, or at least of two tracks.

Several miles of the Chesapeake and Ohio canal have been constructed, along the bottoms of the Potomac, for less than the cost of the rails of a single railway track; one half mile, on level ground, at little more than $1,800; and the possibility of this is obvious to any engineer, who will take the trouble to make a calculation of the necessary depth of cutting, to supply the banks of a canal, where you can choose its level.

It is not, however, more so, than what the same engineer attempts to prove in relation to "other routes of canals and railroads," than those of a few thousand feet under the precipices of the Potomac, to which he first gives his candid attention.

The liberality of his course of inquiry towards the Chesapeake and Ohio canal is here again manifested in his statement, "that, so far as the structure of this canal has been prosecuted, it has been understood," he does not say by whom, "that the estimate of its cost, at $5,000,000 between Georgetown and Cumberland, has been found to be wholly inadequate; and *he is of opinion*, that, unless the dimensions of the canal be contracted, or the work be made less permanent in character, the estimate first mentioned, that of $8,174,000, will be not far from the amount which that work will have actually cost, *shuld it ever be completed*, to Cumberland."

It is now, well known, that no survey, of any description, for a railway up the left bank of the Potomac, had been attempted, before the purchase, by the Baltimore and Ohio Railroad Company, with a celerity unexampled, of the ground along the difficult passes, on the left bank of that river, where they admit, themselves, that no choice of way existed; and while it is believed that no working survey has even since been completed of the entire route of a railway from the Point of Rocks to Cumberland, it is not a little astonishing, that the chief engineer of this company, who has so little reliance on the calculations of experience, entertains the *confident* belief that the railway from Baltimore to Cumberland, will not exceed, in cost, $5,000,000!

He also believes, it appears, [that the expense], of constructing a canal, from Baltimore to the "Point of Rocks, would be *double*, what the railroad, *between the same points*, will cost:" while the reason that he gives for this belief, is, that the estimate reported by Dr. Howard, "for a canal from Georgetown to Baltimore, the length being 44¾ miles, amounted to $2,800,000." Now, this author of the comparative estimate of the cost of railroads and canals, might have as well assumed any other estimated route for a canal, as this, for his standard of comparison; since the Baltimore and Ohio railroad, in passing to the Point of Rocks, occupies but a very small part, if any, of that space, which Dr. Howard surveyed for a canal, from Bal-

timore to Georgetown; and this engineer very well knew, at the same time, that the estimate of the cost of this canal, was founded on the same erroneous data, which led Dr. Howard, in conjunction with the United States' engineers, to compute a canal with a cross section of 202.5 feet, only, at a price greatly exceeding the actual cost of one of 306 feet, along the valley of the Potomac, and over very nearly the same ground. Let the estimate for the Baltimore canal be reduced by a reference to the actual cost of the Chesapeake and Ohio canal, and the estimated cost of that, by recurring, from its actual, to its former estimated dimensions, and a canal from Georgetown to Baltimore, 48 feet wide and 5 deep, would appear capable of construction, by this fair standard, at less than the present estimate of the sixty-seven miles of railroad from Baltimore to the Point of Rocks, or of a substantial railroad from Baltimore to Georgetown.*

It is not a little surprising that, in reply to the grave call of a Legislature, this engineer did not recur to the ascertained cost of the archetype and model of all modern railroads, that between Manchester and Liverpool, for one term of his comparative estimate of the cost of railroads and canals. In looking to his other term, it is equally strange that he should have passed, unheedingly, by the numerous canals of the United States. Those, for example, of New York, of Pennsylvania, and of Ohio.

By an early report of her Canal Commissioners, the canals of New York were stated to have cost about seventeen thousand dollars a mile. By the last report of the Canal Commissioners of Ohio, 190 miles of canal in that State, extending from Lake Erie to the north end of the Licking Summit, and now regarded as finished, have been constructed, with all their costly appurtenances, at a price which, embracing every contingent expense, is less than $11,000 a mile; or, by $2,000 short of the cost of the mere rails of a double track, on stone sills, of the Baltimore and Ohio railroad, according to the same engineer.

This comparison omits any allowance for graduation, and contingencies of every description. Yet this practical civil engineer tells the Legislature of Maryland, "that, in the most favorable grounds along the river bottom lands" of the Potomac, it is presumed, "the expense of the canal, would exceed that of the railroad, from 25, to 50 per cent." If the chief engineer of the Baltimore and Ohio railroad could have awaited the late annual report of the Liverpool and Manchester Railroad Company, he would have seen that a railway of only two tracks, overcoming in 32½ miles an elevation of less than 150 feet, had cost, including all contingencies, £865,000 sterling, a sum exceeding 120,000 dollars per mile; while he must have known, that the magnificent canal of Languedoc, in length 148 miles, with a mean breadth of 49 feet, and overcoming a summit of more than 600 feet, with a lockage of 1200—though constructed with the revenues of the French monarchy, cost much less per mile than the half of that sum. He would also have perceived that the present charge for transporting a bale of cotton, on the Liverpool and Manchester railroad, is 10*s.* sterling a ton for a distance of 32½ miles, and 5*s.* sterling for each passenger. Rates which, for commodities, are treble the cost of transportation, for like distances, on the canals of Pennsylvania and New York; and for passengers, more than double the cost of transportation for the greater distance of 56 miles, on the canal between Glasgow and Liverpool.

* The same engineer has since actually presented to the Baltimore and Ohio Railroad Company, by whom it has been submitted to the Governor of Maryland, an estimate for this road, which makes its cost near 50,000 dollars a mile.

As to the cost of repairs on canals and railways, which must regulate their nett profits, experience, until matured by time, can furnish no measure of their relative extent. Much must depend upon the excellence of their construction. A celebrated constructor of steam engines and carriages, who has recently returned to America, from England, apprises the public, that there is no railroad in America, of sufficient strength to bear the free use of locomotive engines; and whether the railroad of Liverpool and Manchester will sustain their use, with profit to the company, by which that costly work has been constructed, remains to be verified by the fulfilment of promises not yet realized, and against the suggestion of nine months' experience, on a perfectly new and very smooth road.

Lest the estimate of this board, that the canal between Georgetown and Cumberland will cost about 5,000,000 dollars, should appear to be impaired, by passing unnoticed another error of the same engineer, to whose calculations reference has been so often made, it is proper to remark, that if the experiments on the Ardrossan, and other canals of Scotland, have not destroyed all apprehension of injury to the banks of a canal, by boats moving on their surface with great velocity, the remedy hitherto applied to prevent such injury, is much less expensive than this engineer supposes, who charges 5,000 dollars a mile for walls calculated to protect the inner slopes of a canal from washing. More than 40,000 superficial yards, one foot in thickness, of such walls, have already been constructed in the Chesapeake and Ohio canal, at the cost of less than sixteen cents a yard, including the price of transporting a part of the stone some distance by land. The residue of this work, for which the canal excavation furnishes an abundant supply of materials, has been permitted to await the introduction of water into the canal, that the stone may be transported by boats tracked by horses. Allowing twelve cents, a cubic yard, for transportation, but reducing the height of the wall as has been found expedient, the cost of such an inner lining for 2½ feet, on each side of the canal, immediately below the surface of the water, which is found to be all that is necessary for its object, would be reduced to less than $1000 a mile.*

For several miles together, the Chesapeake and Ohio canal has a border of solid rock on one side, which needs no lining for its protection. In other places, it is spread out to such breadth, by a single embankment on the side next the river, that it needs no such lining along either slope. When compressed, as it is, for less than a single mile on a line of 48, within a breadth under 60 feet, it is always bounded by rock, which yields stone for its inner

* The first inside slope wall, or pavement, on the Chesapeake and Ohio canal, was made, by special contract, of stone, which the contractor found it more convenient, and was permitted to leave in the bed of the canal, at the cost of 8 cents the square yard. The masons engaged in the construction of this inside wall, which is the best on the line of the canal, acknowledged that they made by it, their customary day's wages. In this case, the pavement extended from the bottom of the slope to within two feet of the top of the embankment, on both sides of the canal.

On section 14, by advice of a New York canal commissioner, the wall was constructed on a bench formed in the sloping embankment, about 4½ feet below the top of the embankment, and extended up the bank, with very little slope, to within two feet of the top. So that here the wall is 2½ feet high. This height of wall, the commissioner affirmed, from the experience of the New York canal, was quite sufficient, and so it has been here found, to guard the bank from abrasion, either by high winds or the motion of the boats engaged in its navigation. This wall was put up at 12½ cents the perch. In one mile of the canal, supposing both shores of it to be so protected, there would consequently be 1760 lineal yards × by 10 feet = yards 3⅓ × 1760 = 5866 yards, which, at 12½ cents per yard, would cost $733⅓ a mile. At 8 cents, the square yard, this sum would be less than $500 a mile: at 16, it would not reach $1000, as stated in the text.

pavement, free of the cost of transportation, so as to save a part of the above estimated expense.

It is somewhat remarkable that the chief engineer of the Railroad Company should add 5,000 dollars a mile to the cost of the canal, at the Point of Rocks, for its inner lining of stone, when he takes care to lodge it, as well as the railroad, on a bed of rocks, and provides, in an estimate, of the joint cost of the two works, for a partition wall of three feet thickness between them.

"The residue of his comparison of railroads with canals, is equally impartial with the preceding, and obviously designed to withdraw the patronage of the State of Maryland from her canal, for it is hers unless she chooses to expel it from her territory, to the Baltimore and Ohio railroad. The far greater part of his facts are inconsistent with each other; his assertions are without proof; and his principles have been refuted by experience, as we have seen.

"What shall be thought of the judgment which, under the climate of Maryland, and in relation to the Potomac, pronounces that, "from the combined effects of floods, breaches, repairs, drought, and cold, the average duration of the navigation of a canal, *inour climate,* is reduced about one half of the year?"

"The Chesapeake and Ohio canal was easily kept open for navigation, and actually navigated with facility, when frozen to the depth of very near three inches. In the late hard winter, its use was not suspended by ice till after the middle of January.

"Does any man believe that the Potomac river will not supply an adequate quantity of water, in any drought, to feed a canal along its banks; or that internal intercourse will be promoted, and "transfers and transshipments, adding to the expense and risk of transportation, be prevented," as this writer insinuates, by substituting a railroad for a canal, along the margin of a river which has already upon its stem and its branches above tide-water, a descending navigation, practicable at some seasons, of 750 miles; or that a country will resort to railroads instead of canals, which has a coast, thus bordering navigable water, for 1,500 miles, counting both shores of this river, and of its often navigable tributaries?

"How well does it fit the occasion of his letter, to comprehend, among the advantages of railroads over canals, that the latter occupy the *best lands* of a country, when the very railroad, which this engineer is endeavoring to exalt in value above the Chesapeake and Ohio canal, is seeking to establish a right to pre-occupy the very ground along the Potomac, so often surveyed for the construction of the canal? Let railroads, which are admirable time and labor saving inventions, be constructed wherever the trade which they are designed to accommodate, will defray the cost of their construction and use, and they can either be rendered more beneficial than canals, or canals cannot be made."

Extracts from the report of Colonel John J. Abert and Colonel James Kearney, of the United States' Topographical Engineers, upon an examination of the Chesapeake and Ohio canal, from Washington City to the "Point of Rocks;" made by order of the Secretary of War, at the request of the President and Directors of the Chesapeake and Ohio Canal Company.

"To Brig. Gen. Gratiot, *Chief Engineer U. S. A.*

"Sir: In obedience to your orders of the 11th of May, we have made the examination of those parts of the Chesapeake and Ohio canal which are

"completed and under construction," and have now the honor to report the result of our observations.

"The first part of the work which we visited, was the basin at Georgetown. This basin is formed by a dam thrown across the mouth of Rock creek, forming an extensive quay or landing place, one of its faces being on Rock creek, and the other on the Potomac river. The length of the quay on the Potomac face, is one thousand and eighty feet: two hundred feet of which is occupied by a tumbling dam, for the delivery of the surplus water of this creek, and thirty-eight feet occupied by the tide lock, leaving eight hundred and forty feet front on the Potomac river. Piles, each one foot in diameter, were driven throughout the whole extent of the river front, touching each other, and then at every three feet of the interior, to a distance of twelve feet, until they refused a pile driver of eleven hundred pounds. The whole of these piles were then connected by heavy timbers, bolted to the head of each pile, and this frame work was then united by a course of hewn timbers fitting close to each other, and five inches thick, and well secured to the frame and piles. On the front of this pile work, there is a well laid dry wall, twelve feet thick, and seven feet high, including the coping. Strong and frequent ties of timber firmly connected with the pile work, are extended under the soil of the quay. Until these were fixed, a slight curving had been observed in a part of the wall, but, since that time, not the least indication of yielding is perceptible, nor do we think there is any just ground of fear for the durability of this part of the work. It stood without injury the unusual freshet of the river of the last spring, on the breaking up of the ice.

"The width of the quay is one hundred and sixty feet, except at the city end, where it narrows to eighty feet. Sixty feet in width of the centre of this quay, is intended for warehouses and stores, and the rest of the space is to be left open for streets and landing places.

"A bridge is constructed over the head of the tumbling dam, connecting the Georgetown part with the city part of the quay. This bridge is of timber, on piles—a simple, but substantial structure.

"The inside of the quay forming the Rock creek face, is protected by a well laid dry wall, surmounted by a stout hewn timber coping, bound to its place by tie-timbers extending some distance into the soil. The whole of the space between these two fronts, is already filled up with earth.

"The walled face of the basin also extends upon both sides of Rock creek, to the second bridge, constituting an entire length of walling on the inside of the basin of five thousand five hundred feet, (about 300 feet of the wall is yet to be laid,) and enclosing an area of eight and one-quarter acres.

"But the real extent of this basin is much greater, as the water of this creek, when raised by the dam at the quay, will be deep and navigable up nearly to Patterson's paper mill, and will extend over an area about twice as great as that included between the walls."

"The width of the canal up to Frederick street, (in Georgetown,) is forty-six feet, and its depth six; from this street it gradually widens to eighty feet, and increases in depth to seven, which it maintains through the remaining part of this level up to lock No. 5." "This level is continued from lock No. 4 to lock No. 5, near the Little falls, throughout a distance of about four miles."

"Lock No. 5 is similar in its plan, dimensions, and materials, to those we have heretofore spoken of. It appears to have been faithfully built, and is very tight. The great dimensions of the canal, heretofore stated, termi-

nate at this lock, beyond which the width, at the water surface, is sixty feet, and the depth six."

"Lock No. 10 is built entirely of granite. It is a fine structure, extremely tight, and has every appearance of durability. We take this opportunity to remark, that all the locks previously noticed, were also tight. We saw no leaking or spouting from the walls; and we examined them immediately after they were emptied, when such defects, if they exist, will always show themselves."

"Lock No. 21, is similar to those previously noticed, and has all the appearance of faithful work; is tight, and exhibits no evidence of yielding."

"This last lock (No. 20) has the general lift of the locks of this canal, of eighty feet, and completes the series necessary to surmount the elevation of the Great falls of the Potomac." "The line of the canal from the Little falls to this lock was replete with difficult passes, which the engineer appears to have attacked with boldness, and to have admirably surmounted."

"The usual time employed in the passing of a lock by the packet-boat, is four minutes. A passage, however, may be readily effected in three minutes and a half; and were informed that, in an experiment of several passages, the average of the time occupied was but three minutes."

"The culverts are of an admirable length, extending well and sufficiently through the embankments."

"Over this river (Seneca) an aqueduct is constructing. It will consist of two piers and three arches. The sheeting, as well as the ring stone, are to be cut to the proper angle, and "laid in hydraulic mortar." We believe that this structure will be both beautiful and enduring."

"The aqueduct over the Monocacy is four hundred and thirty-eight feet long, from the face of one abutment to the face of the other, and the masonry of the abutments and wing-walls extends ninety-six feet farther. The whole work will consist of two abutments, six piers, and seven arches, to be fifty-four feet span, with a rise of nine feet. The two arches which rest against the abutments are conducted within the abutments by what is called a blind arch, down to the rock foundation. The masonry of the abutments and piers rests upon the solid rock which forms the bed of the river, and which had been previously cleared and prepared for the purpose. The piers and abutments are thirty-three feet four inches long, exclusive of the pilasters. The piers are ten feet wide above the water table, and fourteen feet wide, and thirty-eight feet long at the foundation, which last dimensions are preserved up to within one foot of the low water surface."

"We visited the quarries. The stone lies high, and is of easy access; its color a dull white. It is of the kind usually called by workmen mountain granite, but by geologists it would be called gray wacke. It splits well, hammers without fracture, is fine grained, and, in our opinion, a very lasting stone."

"The work was executing in good faith by the contractor, and was vigilantly watched and inspected by the engineer. We consider the plan judicious, as well as its execution, in which are united the true principles of economy, usefulness, and durability."

"It may be proper to remark, that, in the whole length of the canal between the aqueduct over Seneca, to that over the Monocacy, wherever the embankment touches in the river, it is carefully protected against its action by extended and well constructed walls of dry masonry. These walls, so frequently mentioned in our report, might, without explanation, be consider-

ed objects of extravagance; we will, therefore, add, that the valley of the river occupied by this canal, is bounded, to a great extent, by high rocky cliffs, which, in many places, project into the water, leaving the engineer no other course than to blast his path through them, and to establish the foundation of his embankment in the river itself."

"The length of the canal between locks 21 and 22 is three miles. Throughout the greater part of this distance, the embankment on the river side is sustained by a beautiful and well built sloping stone wall of dry masonry, resting upon a judiciously laid footing, and rising to the top of the embankment; the inside slope of which is rivetted also with a slope wall, laid from the bottom of the canal. There is one continued line of two miles of this walling, curving with the canal, in which we did not observe the slightest indication of yielding or of weeping in any part of it. In parts of this line, the rock excavation was very great, and the superfluous stone is judiciously placed outside of the walling, and in a manner to relieve it from the current of the river."

"A pit is excavated, and part of the foundation laid for another roadway, intended for the convenience of Conrad's ferry. We cannot forbear here expressing our decided approbation of this method of crossing canal lines, over the more usual method by bridges."

"We observed a paved ford to accommodate the adjoining farms. This ford can be conveniently used when the water in the canal is aboutfour feet deep—when deeper, it is contemplated to use a large boat at this space; for which purpose docks are constructed on each side of the canal, that the boat may lie out of the canal line."

"We are fully aware, that, after all we have said, we have not yet given an adequate idea of the great and interesting work we have been directed to examine. The difficulties which have been surmounted—the quantity of labor it has received—the vast amount of rock excavation—the extent and excellence of the walls of dry masonry—the durable aspect of all the structures—the great and imposing dimensions of the canal—the judicious adaptation of the excavations to the fillings and embankments—can be duly appreciated only by visiting the work.

"The trade of the canal in the part now in use is very active; there is, however, a necessity for a system of regulations to govern the boatmen."

Extract from the report of the United States' Board of Internal Improvement, accompanying the President's message to both Houses of Congress, of the 7th of December, 1826.

"PLAN AND ESTIMATE OF THE CANAL.

"The transverse section of the canal is exhibited on the sheet No. 3. The breadth at the bottom is 33 feet; at the surface, 48 feet; the depth of water, 5 feet; the tow path, 9 feet wide; the guard banks, 5 feet at the top; the surf berms, kept on the level of water, 2 feet wide each; the tow path, and top of the guard bank, 2 feet above the surface of the canal.

"This transverse section is to be modified *where local circumstances require it*, and more especially in the cases of deep cutting, steep side cutting, embanking, and also where the canal is supported by walls. In the framing of the plan, a due attention has been paid to these modifications, with a view to conciliate the convenience of the work with the strictest economy. The

depth of 5 feet has been preserved throughout the line, but the *breadth has been often much lessened.* As to the surf berms, they are intended to protect the slopes from being washed off, as, also, to lessen the resistance opposed to the boat, by affording to the eddy water a free passage.

"We must submit, however, the reasons which led us to propose the above dimensions.

"The experiments made in 1775, by the French academicians, (D'Alembert, Condorcet, and Bossut,) have shown: 1. That the resistance of water to the perpendicular motion of a given plane, may be regarded as proportional to the square of the velocity; 2. That the velocity being the same, the resistance of water may be considered as proportional to the area of the plane; 3. That these results obtained only in the case of an indefinite expanse of water; 4. That, in narrow canals, the resistance increases in a more rapid ratio than the square of the velocity.

"To attenuate, as much as practicable, this inconvenience, researches have been made to ascertain what should be the ratio between the transverse section of the canal, and the transverse section of the boat, in order that the boat might move through such a canal as through an indefinite expanse of water. Experiments made on the subject by the celebrated Chevalier Dubuat have shown that, to attain this result, the cross section of the canal ought to be, with moderate velocities, 6.46 times across the section of the boat, and the water line 4½ times the breadth of the boat.

"Adopting, to preserve uniformity, 13½ feet for the breadth of the boats used on the Chesapeake and Ohio canal, (which is the breadth of the Erie canal and of the Ohio canal boats,) if we suppose the draft to be three feet, the prow to be rectangular, and the sides and bottom of the boat to conform to it, the cross section of the boat will be 40.5 square feet. Taking, now, this area 6.46 times, we find 261⅔ square feet for the cross section of the canal, through which the boat would not meet with a greater resistance than through an indefinite expanse of water. The water line should be 60¾ feet, that is, four times and a half the breadth of the boat.

"Were not expense to be taken into consideration, these dimensions might be recommended; but fitness of the work and strict economy must be reconciled as much as practicable, and it is in such a view that smaller dimensions are to be fixed upon.

"It is to be remarked, that the distance from Georgetown to Pittsburg, in following the line of canal, is 341¾ miles, which, at the rate of 2½ miles per hour, will be travelled in about - - - - 136 hours

The ascent and descent, amounting together to 3,158 feet, will require, at the rate of 1 minute per foot, about 52

Distance, in time, from Georgetown to Pittsburg, - 188 hours.

"Though a number of canals, selected among those executed to this day, might afford together the distance and lockage found for the Chesapeake and Ohio canal, yet there is not, within our knowledge, any line of the same extent requiring even 1,800 feet of ascent and descent taken together: the Erie canal requires 688 feet for 362 miles; the line from Liverpool to London, 1,451¼ feet for 264 miles; the canal from the Rhone to the Rhine, connecting Lyons with Strasburg, has about 1,458 feet of lockage for a length of 200 miles. The proposed canal has, therefore, as to time, a decided inferiority, when compared to a canal of the same length, but having a less amount of lockage; and it becomes, in the present case, indispensable to reme-

dy this inconvenience. The means we propose consists in the increase of the dimensions of the cross section of the canal, with a view to compensate by a greater weight transported without additional power for the virtual increase of distance caused by so great an amount of lockage.

"We have shown that this section ought to be 261 square feet, with a water line of 60 feet, to procure a boat 13 feet 6 inches in breadth, the advantage of moving on the canal as on an indefinite extent of water. After many trials and minute calculations, we have concluded to adopt, for the contemplated canal, the $\frac{4}{5}$ of the foregoing results, viz. for the cross section, 208 square feet, and for the water line 48 feet; and from these data we have framed, with a depth of five feet, the general transverse profile of the canal as exhibited on the sheet No. 3.

"Let us now compare this profile to one having 40 feet at the surface, 28 feet at the bottom, and 4 feet in depth—the boat used being the same for both, and having 13½ feet in breadth, and 3 feet draft.

"We find, by calculations, that, the velocity remaining the same, the resistance to the boat moving in the 48 feet canal, is to the resistance to the same boat moving in the 40 feet canal, as 1.21 to 1.58, or as 100 to 130. Therefore, at the same rate of velocity, 100 horses will, on the 48 feet canal, perform the same work as 130 horses on the 40 feet canal; and, with the same towing power, the weight transported on the 48 feet canal will be to the weight transported on the 40 feet canal as 130 to 100.

"But the depth of the 48 feet canal being one foot greater than the depth of the other, let us examine what would be the comparative resisitance of the boat being immersed 4 feet into the 48 feet canal, and but 3 feet into the other. We find, in this case, the ratio to be 1.47 to 1.58, or 100 to 107, and we infer from it that, with a gain of about seven per cent. of towing power, the weight transported on the 48 feet canal will be one-third greater than the weight transported, during the same time, on the 40 feet canal.

"The foregoing considerations show, that, in determining the transverse section of a canal of great length, and with a dividing summit level, the amount of lockage must have a due influence upon the breadth and depth of the water section. And, indeed, taking into view the great distance and considerable lockage belonging to the present case, a cross section larger than that recommended might have been suggested, had not a regard to economy, and to a competent supply of water during the dry season, forbidden it.

"However, the transverse section, as just proposed, may be deemed sufficient to fulfil, in a satisfactory manner, the main requisite for which it has been intended. And, in order to remove all doubt, let us compare, as to amount of transportation, the contemplated Chesapeake and Ohio canal with another of the same length, but whose lockage would be 600 feet only, with a transverse section of 40 feet at the surface, and 4 feet in depth.

"The rate of travelling being supposed, for both, 2½ miles per hour, and one minute allowed for each foot of lockage, 60 feet will be, as to time, equivalent to 2½ miles; and these canals will then compare as follows:

"The Chesapeake and Ohio canal, having 3,158 feet of lockage in a distance of 341¾ miles, is equivalent, as to time, to a single level canal of 473 miles, which would require 189 hours to be travelled from one end to the other.

The 40 feet canal, having 600 feet of lockage in a distance of 341¾ miles, is equivalent, as to time, to a single level canal of 367 miles, and which

would be travelled in 146 hours, from one end to the other. But it has been shown, that, on the first canal, the amount of transportation being expressed by 130, it will be 100 on the 40 feet canal—the velocity and towing power remaining the same in both cases. Comparing, now, this ratio of 130 to 100 with that of the times employed to travel, respectively, each canal, viz. 189 hours to 146, it is found that these ratios are equal. Therefore, on either of these canals, and notwithstanding a difference of 2,558 feet lockage, an equal weight will be transported during the same time, and with an equal towing power; a result entirely due to a larger transverse section having been assigned to the canal whose lockage is greater."

"After the enlarged dimensions of sixty feet by six feet for the volume of water in the canal, were recommended to the Committee of the House of Representatives on Roads and Canals, by the chairman, he addressed a letter of inquiry to Gen. Bernard, on the comparative resistance of the motion of a boat of given structure and burthen on such a canal, and one of the dimensions recommended by the board over which that officer presided. The annexed letter contains his answer to this inquiry:

"*Letter from Gen. Bernard to Hon. C. F. Mercer.*

WASHINGTON CITY, *February* 17, 1827.

"SIR: I have the honor to forward to you the result of the calculation you asked for, in relation to a canal 60 feet wide at the water line, 45 at the bottom, and 5 feet deep.

"The cross section of the boat remaining as assumed in the report on the Chesapeake and Ohio canal, such a boat would, for the reason set forth in this report, move, at moderate velocities, on 60 feet canal, as on an indefinite extent of water.

"The resistance proved, in this case, by the boat, being expressed by 1, the number 1.21 will represent the relative resistance in a 48 feet canal, and 1.58 that in a 40 feet canal. Thus, with a towing power of 100 horses, the same work will be performed on the 60 feet canal as with 121 horses on the 48 feet canal, and 158 on the 40 feet canal—these two latter canals being here supposed to retain the respective cross sections assigned to them in the aforesaid report.

"Now, assigning to these two canals the same comparative length and amount of lockage as alluded to in the report, they become on the same footing as to towing power, but the sixty feet canal has the same length and amount of lockage as the 48 feet canal: therefore, it will have an advantage of 21 or 18 per cent. over the latter, as to towing power, and the same advantage over the 40 feet canal. In other words, 18 per cent. more weight would be transported during the same time, and with the same towing power, on the 60 feet canal, than on the two others.

I have the honor to be, sir, very respectfully, your obedient servant,

BERNARD, *Brig. Gen.*

To the Hon. C. F. MERCER, M. C., *Washington City.*

Extract from the first annual report of the President and Directors of the Chesapeake and Ohio Canal Company.

"The enlargement and elevation of the Chesapeake and Ohio canal, from the lowest dam and feeder to the entrance of the streets of Georgetown, have been prompted by a due respect for the well known object of the express condition attached to the United States' subscription of a million of dollars, added

to the desire on the part of this board, sanctioned by the voice of the stockholders, of promoting the application of water power to domestic manufactures, at the very advantageous sites afforded, immediately above, as well as near, the termination of the canal.

"It is well understood that this cannot be effected without some injury to the navigation of the canal, for the whole, or a part of that distance, and it should not be encountered without an equivalent benefit to the company, and to the community.

"Should the pretensions of certain individual claimants, holding lands on both sides of the Potomac, to the exclusive use, for manufacturing purposes, of the water of this river, the highway, but recently, of two sovereign States, be not sustained, the profit to be derived to the company, from the proposed application of part of the water of the much enlarged canal, will amply repay the cost of its enlargement, while the public, as well as the stockholders, will be compensated for some delay in their ascent of this short portion of the canal, by the rapid growth of their common market. The company cannot be a loser, though the construction given by these claimants to the charter of the late Potomac Company be confirmed, by the judicial interpretation which they have sought of its true import, and of its subsequent modification by the charter of this company.

"Still, it remains, in the judgment of the board, a question to be determined hereafter, whether the enlargement of the dimensions of the canal, beyond fifty feet, shall be extended above the mouth of the Shenandoah, and through its ascent to Cumberland.

"As far, at least, as the former point, a prudent regard to the competition which this commercial avenue has to encounter, not only for the trade of the west, but of its own tributaries, the valleys of the Potomac, and of its navigable branches, required that the board should avail themselves of all the aid which science could supply to fix this commerce in its natural channel.

"The acquisition of at least sixty per cent. to the facility of transportation, upon the broader and deeper channel provided for the Chesapeake and Ohio canal, is believed to be worth more than an advance of twenty per cent. upon the cost of its construction.*

"In the same spirit which has given these enlarged dimensions to the plan of the canal, the board have diligently and laboriously sought, by negotiation and argument, as well as by appeals to legislative authority, to preserve the entire line of canal, above Georgetown, free from the dangerous, inconvenient, and costly obstruction of permanent bridges. They have invoked the interest as well as the patriotism of individuals, and the wisdom and policy of juries and legislatures. The appeal to the last has been in but one case availing; but they have been able to suspend the erection of any bridges for the present; and still seek, by the purchase of small tracts of land, lying between the canal and the river shore, to diminish the number of persons interested in opposing their wishes. Until a modification can be had of the

* "By an early order of the President and Directors, it was determined to verify, by experiment, the relative advantages afforded to navigation in boats of given dimensions, by large and small canals. For this purpose, troughs were made, each 30 feet in length, designed, by their relative capacity, to illustrate the proportions of the New York and Ohio canals to the Chesapeake and Ohio canal.

"Although the result of these experiments demonstrated the very great superiority of the larger over the smaller canal, so many defects were apparent in the manner of arriving at the results, that the board determined to ascertain, by the actual construction of a small part of the canal, the exact difference of the resistance offered to the passage of a boat of given dimensions and cargo, on these canals."

charter of the company, conveyances for such parcels of land are proposed to be taken to trustees, for their future use.

"The entire quantity of land, from the District of Columbia to the Kitoctin mountain, lying between that required for the canal, and the river, was long since found, by actual survey, not to exceed 1,300 acres, of which, more than 500 are reported to be inarable. This land is not in one body, but in narrow slips, the property of numerous proprietors; and the erection and maintenance of permanent bridges for the accommodation of each, would, apart from obstructing the navigation of the canal, cost more than the land itself is worth, at any fair estimate of its value. From the Monocacy to the Point of Rocks, along the far better part of this country, the quantity of land, exclusive of the precipitous banks of the river, cut off from the main by the canal, does not comprehend fifty acres; for five miles, it does not exceed six acres; the canal having been generally, always where practicable, conducted along the margin of the river, as well to avoid interruptions, as for the sake of better ground, and a more ready access to the canal, itself, from the opposite shore of Virginia. Although much more deeply interested in procuring a ready passage across the canal than her neighbor, whose territory it immediately borders, this State has readily assented, where the company may deem it expedient, to the substitution of ferries, for bridges over the canal. Between Harper's Ferry and Georgetown, but few public highways at all interfere with such a provision. One of these may be provided for by a very elevated bridge, another by a pivot bridge over a lock immediately crossing it; and, in some cases, ferries, attended with no danger and very little delay, may be resorted to, with the approbation of the local authority charged with this branch of the public police.*

"Should the confident hope, inspired by intelligence recently received from the canals of Europe, as well as of the United States, be confirmed, and it be found practicable to substitute, on this canal, the application of steam for animal labor, as its propelling power, its enlarged and unobstructed surface will favor, alike, economy of transportation and the comfort of the traveller: and render that, which is obviously the shortest, also the cheapest and the most agreeable channel of intercourse between the eastern and western States. Boats of elevated cabins and double decks, propelled by steam, will countervail, by a velocity of seven or eight miles an hour, the transient suspension of their motion by the locks; and by supplying the wants of every description of passengers, will afford, at the same time, cheap accommodation to the needy, and multiplied enjoyments to the rich. By such means will this improved channel of internal commerce, national in its end, as it is, in part, in the resources provided for its accomplishment, confirm the union of the States, without an undue increase of the power of their common Government. And if, in the prosecution of such an object, some expense may seem to have been encountered which parsimony might have denied, the patriotism from which this enterprise sprung, and on which it must continue to rest, will not, it is presumed, reject the powerful appeal which an enlarged economy, in conducting such a work, addresses to the Legislatures of the Federal Government, and of the States who share the cost of its prosecution with public spirited individuals. To these individuals themselves, the argument in favor of the plan adopted by the board is, as simple as it is intelligible, that a more costly canal, with an active navigation,

* It has been decided, by a Judge of the Court of Appeals in Maryland, that the company cannot be compelled to erect bridges across the canal.

will yield a better dividend, than one of cheaper dimensions without any commerce whatever."

Extracts from the reports by Messrs. Roberts and Cruger, of the examination, survey, and estimate of the western section of the Chesapeake and Ohio canal; and from the first report of the United States' Engineers, of the examination and location of that section in 1824.

GEORGETOWN, *Sept.* 2, 1829.

To the President of the Board of Directors of the Ches. and O. Canal Comp'y:

SIR: The summit level of the Chesapeake and Ohio canal, embracing the tunnel through the Alleghany ridge, the deep cuttings, and the basins at each end, and the feeder from the Casselman river, are the subjects of this communication.

All which is respectfully submitted.

NATHAN S. ROBERTS,
Engineer of the second division C. and O. Canal.

The Alleghany ridge, through which the tunnel is to be cut, is supposed to be sandstone, with a mixture of slate: this opinion being formed from the quality of the rocks which appear on the surface, and in cliffs in the sides of the mountain at various heights. And, in corroboration of this opinion, it is proper to state, that the same qualities of stone present themselves both above and below the level of the tunnel, along the line of the canal, in detached boulders and large masses, variously disposed in the bed and on the margin of the rivers, and in the *debris* or fine broken stone, which in many places cover the steep sides of the mountain; and, proceeding west, the regular layers and horizontal cliffs and ledges of sandstone, appear in all the steep hills and mountains through which the channel seems to have been worn down by the Casselman and the Yougheogany, till they have united and passed through Laurel hill. And the same quality of sandstone, with veins of slate, appears in horizontal strata above the coal veins, in the high hills in the vicinity of the Monongahela and Pittsburg, and in the coal district near Cumberland. Frostburg and Westernport sandstone is found in the same situations. In a few places these stone are of the millstone grit, and wrought for that purpose. This was observed on the national road, and about twelve miles down the valley of Wills' creek; but, in general, they are a soft sandstone, suitable for locks and all other purposes where cut stone work is necessary.

The elevation of the tunnel or summit level is 1972 feet above low tides at Georgetown, and 1273 feet above low water in the Ohio at Pittsburg; and the difference shows that the Ohio river at low water at Pittsburg is 699 feet above common low tides at Georgetown.

The length of the summit level consists of the tunnel of 4 miles, to be excavated through the Alleghany ridge, and, at each end of the tunnel, a deep cut and a basin are extended, and terminated by a lock.

The length of the deep cutting and the basin at the eastern end is 40 chains, and the length of the deep cutting and basin at the west end is 1 mile, making the whole length of the summit level, from lock lo lock, 5 miles and 40 chains.

The dimensions of a transverse section of the interior of the tunnel, and upon which the following calculations are presented, are shown in the annexed diagram, and are as follows, viz.

The water for the passage of boats through said tunnel is to be 6 feet deep and 17 feet wide. The towing path to be 7 feet high (rising one foot above water) and 5 feet wide. The width of the tunnel above the towing path will be 22 feet, and the height 7 feet to the spring of the arch, which is supposed to be equal to a semicirle of 11 feet radius. On each side of the bottom of the tunnel, a drain is to be sunk in the rock, below the bottom of the canal, equal to a cut of two feet square, with a descent of 3 feet in the distance from the centre to each end of the tunnel. A section of the tunnel, according to these dimensions, is equal to 52⅓ superficial yards; and the solid contents, in 4 miles, will be equal to 368,428 cubic yards.

In the prosecution of this work, it is calculated that 120 men, divided into relays of 30 men each, may be advantageously employed at blasting and quarrying at each end of the tunnel: one company to perform 12 hours, and then be relieved by another company, to labor for an equal length of time, and thus proceed through the 24 hours, making, in the result, a force equal to 120 men laboring for 12 hours in each day. And it is computed that, taking a portion of the heading, the side trimmings, and the drain, together with the blasting and quarrying from the breast or body of the tunnel, a good hand will not average less than ¾ of a cubic yard for each day's work. At this rate, 120 men will blast and quarry 90 cubic yards per day.

The tunnel, as above stated, contains 368,428 cubic yards; this quantity, divided by the amount of one day's work, gives 4,094 days, and, allowing 300 days for labor in each year, the time required to complete the excavation of the tunnel will be 13 years and 194 days.

The wages, subsistence, and apparatus, furnished and kept in repair, for each man per day, for blasting and quarrying in the tunnel, is computed, as follows:

Wages per day, on an average - - - - -	$1 00
Board and other necessaries of subsistence per day - -	50
Gunpowder, all necessary tools, and light, per day - -	75
Making the average expense of a day's work of one man -	$2 25

Then, a day's work of 120 men, at the above rate, will be $270; and the amount of rock quarried, in the same time, being 90 cubic yards, the average cost will be $3 per cubic yard.

The expense of transporting the excavated materials out of the tunnel, is computed as follows: a railroad with two sets of tracks is to be laid on and bolted to the bottom of the tunnel, as the work progresses, and to extend past the deep cutting and basin at each end of the tunnel, for the purpose of conveying the materials to a place of deposite and distribution. The expense of a double railroad, equal to the whole length of the tunnel, and half a mile at each end, for the above purposes, is estimated as follows, viz.

5 miles of double tracks will require 105,600 feet of timber, 8 by 12 inches square, and from 20 to 40 feet long, for side rails, delivered at 8 cents per foot - - - - - -	$8,448
10,560 inch bolts, 16 inches long, equal to 23 tons, at 150 dollars	3,450
105,600 feet of rolled iron plates, 1¾ inches wide and ⅜ths of an inch thick, equal to 106 tons, at $130 per ton - -	13,780
1 ton of spikes - - - - - - - -	200
Fitting down and bolting the side rails to the rock, and spiking on the plates on the inner edge of each set of tracks, in a workmanlike manner, and completing the same fit for use, (the bolts being ready made, and the plates punched at the above	

prices,) 6,400 rods of the road, laid as above stated, at 50 cents a rod - - - - - - - - 3,200

Making the whole expense of the railroad - - - $29,070

The materials excavated from the tunnel are to be transported on this railroad, being laid for the purpose, from each end towards the centre, as the excavation of the tunnel progresses.

The load which a horse will draw on such a railroad, and moving at the rate of $2\frac{1}{2}$ miles per hour, is stated variously by different authors, and varies from 8 to 11 tons. But, in these calculations, 1 ton only is estimated for each load, on an average, to be drawn by one horse. The day's work of a man and team is computed at ten hours each day, moving at the rate of $2\frac{1}{2}$ miles per hour, including the time of loading and unloading—making 25 miles for every period of 12 hours.

The cost of a day's work of a man and team is estimated at	- $2 00
One assistant loader to each wagon, to have the loads ready, &c.	1 00
Making the cost of 1 team and 1 loader, per day, equal to	- $3 00

Supposing the materials to be taken from the tunnel to be sand rock and slate, the comparative weight or specific gravity of which is estimated at 2.8, then the weight of the contents of the tunnel to be transported, will be equal to 388,576 tons, to be taken out at each end of the tunnel, at 1 ton per load, or 777,152 tons in the whole 4 miles.

The distance to be travelled out and in at each end of the tunnel is thus stated: at the commencement the distance would be, on an average, 40 chains out and 40 chains back; and, at the centre of the tunnel, the distance would be 2 miles and 40 chains out, and the same distance back, and the number of times the average of these distances is to be travelled, is equal to the number of tons to be taken out at each end of the tunnel—thus stated: $\frac{40+40+200+200}{2}\times 388{,}576\div 80=1{,}165{,}720$ miles to be travelled out and in, from each end of the tunnel. This sum, divided by 25, the estimated length of a day's travel, gives 46,629.12 days' travel for one team at each end of the tunnel. But the transportation is to be done in the same time with the excavation; then, $\frac{46.629.12\times 2}{4.094}=22.8$ teams per day, in the whole, or 11.4 teams per day at each end of the tunnel, to keep even with the excavation.

As the height of the mountain over the line of the tunnel would render vertical shafts very expensive, it is proposed that, when the excavation of the tunnel has advanced about half a mile at each end, or, perhaps sooner, to ventilate the tunnel by means of a steam engine, of about ten horse power, to be stationed, one at each end of the tunnel, with the necessary apparatus, to operate upon one or more cast iron blast cylinders, to be attached to a wooden trunk of the capacity of one foot square, and made of two inch plank, well matched, pitched, and banded with iron, so as to be perfectly air tight, and properly placed and secured on the towing path of the tunnel, and to be extended by additions, from time to time, as may be required. Through this tube, a sufficient quantity of air is to be forced, by the above apparatus, to ventilate the tunnel to its centre.

By a statement received from Mr. John Anthers, steam engine manufacturer at Pittsburg, the cost of a first rate steam engine at that place, of 10 horse power, is - - - -	$1,200
One large air cylinder and apparatus - - - -	500
Transporting the same to the tunnel, and putting the whole in good order fit for use - - - - - - -	300
A wooden trunk of the description above stated, and being extended by degrees to the centre of the tunnel, 10,560 feet, at 50 cents a foot, - - - - - - - -	5,280
The expense of fuel, Mr Anthers states, for 24 hours, is "25 bushels of coal," estimated at 8 cents, or "2 cords of good wood," estimated at $1, - - - - - 2 00	
Cost of attendant and keeping in repair - - 2 50	
Making the whole cost for 24 hours - - - $4 50	
This expense would be necessary about 10 years, then 10+300= 3,000 days, at $4 50 per day - - - -	13,500
Add for contingencies, 20 per cent. - - - -	4,220
Making the whole cost of ventilating one end of the tunnel, for the required time, amount to - - - -	$25,000

Mr. Anthers states further, that such an engine, with but very little repairing, will last 10 years in constant use.

It is proper to observe that bituminous coal, of the best quality, can be obtained within 5 or 6 miles of the west end of the tunnel, and that timber for fuel abounds more at the east end, where coal is not to be expected so cheap; but perhaps it can be obtained at the above estimated price, or found in excavating the tunnel.

Whether the tunnel, or any part of the interior, will require a lining of masonry, is uncertain. If the excavation should be sound rock in regular strata, no lining will be necessary, except, perhaps, at the ends, to give a finish, and prevent the earth from falling into the mouth of the tunnel. The cost of lining, more or less, is not included; and it is proper to observe, that, where a lining becomes necessary, the section of excavation should be so enlarged as to preserve the same dimensions within the lining as are herein expressed.

From the foregoing calculation and analysis of prices, the estimated cost of the tunnel will stand as follows, viz.

Excavating 368,428 cubic yards of rock, at $3 -	$1,105,284
Railroad, with double tracks, 5 miles - - -	29,070
Transporting the contents of the tunnel, viz. 22.8 teams, with one teamster and one loader to each team, for 4,094 days, making 93,343 days, at $3 - - - - -	280,029
Ventilating the tunnel, viz. 2 steam engines of 10 horse power, one at each end of the tunnel, with the necessary apparatus for ventilating, including the expense of fuel, attendant, and repairs, for 10 years, at $25,000 each - - - - -	50,000
Add for contingencies 10 per cent. - - - -	146,438
Making the estimated cost of excavation, transportation, and ventilating the tunnel, amount to - - - -	$1,610,821

Which is equal to $\frac{\$1,610,821}{yds.\ 368,428}$ or \$4 $37\frac{3}{10}$ per cubic yard for the whole quantity of materials required to be taken out of the tunnel, according to the dimensions above stated.

The deep cutting and basin at the east end of the tunnel, is 40 chains in length; the expense of constructing the same is as follows, viz.

Grubbing and cleaning for canal and basin - - -	\$1,000
Common excavation, 44,600 yds. at 20 cts., to be laid in the lining for the basin - - - - - -	8,920
Rock excavation, 15,800 yds. at \$1 - - - -	15,800
	25,720
Add for contingencies 10 per cent. - - - -	2,572
	\$28,292

The deep cutting and basin at the west end of the tunnel, occupy 1 mile: the expense of constructing the same is as follows:

Grubbing and clearing, preparatory - - - -	\$500
Common excavation, 56,320 yds., at 20 cts., to be laid in embankment to form the basin - - - - -	11,264
Common excavation 74,800 cubic yds. at 15 cts. - -	11,220
Rock excavation, 44,000 cubic yds., at \$1 - - -	44,000
	66,984
Add for contingencies 10 per cent. - - - -	6,698
	\$73,682

The dimensions of the deep cuttings for the canal from each end of the tunnel, are 30 feet at bottom of the canal, and the sides perpendicular through the rock cutting, with the usual slope of 3 to 2 given to the earth excavation. The basins will be formed by occupying the valley at each end of the tunnel, where the same is below bottom, for depositing the materials taken from the tunnel in the form of an embankment; and lining the same with the excavated earth, to render the banks and bottom of each impervious to water. Each basin is to be formed with a waste-wier and a lock at the extremity. The distance between these locks is 5 miles and 40 chains, including the basins, the deep cutting, and the tunnel, which compose the length of the summit level."—*Rep. of Roberts and Cruger.*

In the able report of the United States' engineers, on the plan and cost of constructing the contemplated tunnel through the Alleghany, they proposed to expedite the progress of the work, and to cheapen its expense, by sinking over the tunnel forty-eight working shafts. By each of these, two additional surfaces to operate upon, would be presented to the laborers engaged in the tunnel, who work day and night without any interruption, except while elevating them to the surface of the mountain and letting them down, to renew their operations at regular intervals. These would, of course, be so ordered, as to allow ample time for refreshment and recreation to the laborer.

A steam engine of ten horse power, costing about \$1,200, and placed near the summit of each working shaft, would raise, and transport out of the way,

the excavated materials, whether of rock or earth, as fast as the laborers could remove them, within the tunnel, to the bottom of the shaft.

As to the mode of elevating these materials, none would, perhaps, better answer, than an application of the principle, by which the wheat is elevated in a manufacturing flour mill. The empty buckets, on one side of an endless chain of large square links, would balance those on the opposite side, at every stage of the revolution of the drum or cylinder, over which the chain revolves; so that the weight to be elevated would be that only of the excavated materials from within the tunnel.

The cost of all the working shafts recommended by the United States' Board of Internal Improvement, is less than $300,000. If reduced in number, to four only, for each mile, their cost would be reduced in like proportion, so as not to exceed one hundred thousand dollars; while the opportunity, thus afforded, of applying sixteen times the number of hands, which could be worked on the two extremes of the tunnel, would proportionably expedite its completion. Instead, therefore, of consuming thirteen years, with such facilities, the same work would be accomplished in less than a fourth of that period.

Tunnels on railroads, as well as canals, are now so numerous in England, that estimates can be as accurately formed of the money and time required for their construction, as for the cost of any other part of a railroad or canal.

On the canals, alone, of that country, there were, in 1824, near forty tunnels, varying in breadth from nine to twenty-one feet; in length, from 70 to 4,840 yards; their aggregate extent being 62,291 yards exclusive of those numerous subterranean canals for coal boats, of which, on a single canal of the Duke of Bridgewater, there are branches of the extent of eighteen miles on various levels; some sixty yards below the main canal; others thirty-five and a half above it; the greater part of them all being hewed out of solid rock.

The driving of the tunnel through Harecastle hill, on the Trent and Mersey canal, the first canal tunnel constructed in England, cost, in 1776, £3 10*s.* 6*d.* sterling, per yard run. On this single canal, in length 93 miles, with a lockage of 642 feet, there are as many as five tunnels, one mile of the longest of them, which is 2,888 yards in extent, was completed in a single year, though the natural surface of the earth was 210 feet above the tunnel.

Messrs. Roberts and Cruger estimate the entire cost of the proposed tunnel through the Alleghany, at 1,610,821 dollars. To reach this sum, they compute the wages and board of the hands engaged in the excavation, at $1 50 cts. each per day, after allowing 75 cts. more for his gunpowder, tools, and light: the price of a cart, horse, driver, and assistant, working on a railway, and drawing less than half a cubic yard of the excavated materials at a load, at $3 a day. It is not hazarding much to pronounce these allowances at least one-third too high. Carts are never hired on the Chesapeake and Ohio canal, at more than $1 25 cts. per day, the driver being himself found, but finding his own horse; and 80 cents per day is believed to be an adequate allowance for the wages of each hand, including his board. The subterranean character of the work would prevent the reduction of the working days of the month, by changes of weather, and still farther cheapen the operation. Still, as the breadth calculated for the tunnel, in this estimate, is about 17 feet less than the greatest utility of the work would require, after deducting the third of the computed cost of the excavation

and transportation of materials, or 450,000 dollars for the above reason, and the cost of ventilating the tunnel, in consequence of the introduction of the perpendicular working shafts over it; being, in all, half a million of dollars, so as to reduce the cost of the tunnel described by the above engineers, exclusive of contingencies, to less than one million; the residue may be doubled on account of its increased breadth, and the sinking of the shafts; and the cost of the tunnel put down at 2,200,000 dollars, including all contingencies.*

The ratio of the solid contents of the enlarged, to the solid contents of the smaller tunnel, it is admitted, would not be in the direct proportion of their relative breadth; but the increased facility of working in an enlarged space, and the reduction of the cost of transportation, effected by the application of the working shafts, would make this estimate sufficiently great to cover the total expense of a tunnel, within which the canal boats might readily pass each other in opposite directions.

This estimate supposes the tunnel to be conducted through solid rock; and an inner arch of brick or stone to sustain the crown of it, to be unnecessary. Should its passage be through earth, requiring artificial support, the cost of this should be added, but the expense of excavation be reduced, since this necessity supposes the excavation not to be of rock.

Comparative cost of the various works on the western and eastern sections of the State canal of Pennsylvania.

The river Alleghany, uniting with the Monongahela, after having received the Yougheogany 12 miles above Pittsburg, forms the Ohio, at that city, proposed termination of the Chesapeake and Ohio canal.

A canal, from Pittsburg, up the Alleghany, Kiskiminetas, and Conemaugh rivers, to Johnstown, 104 miles in length, has already been constructed. The country along the line of this canal, and that along the Monongahela and Yougheogany rivers, up which, the western section of the Chesapeake and Ohio canal is to be extended, is, in truth, the same. The cost, therefore, of the works on the canal, already finished, may be assumed to be the measure of the cost of the other: and, for this reason, it is deemed expedient to insert the following extract from a communication of Abner Lacock, esq. dated December 15, 1827, to the board of Canal Commissioners of Pennsylvania.

"By the voluminous reports of the engineers, the board will learn what has been accomplished, and what remains to be done, on this division of the Pennsylvania canal, of which the following is a brief extract:

There has been, of excavation of earth - -	yards,	1,522,436
Do do do rock - -		350,837
Embankment made - - - - -		692,718
Stone wall for protection - - - -	perches,	22,390
Mason work in locks, aqueducts, culverts, and bridges		32,307

It must be evident that the principal expense of a lock and canal navigation will arise from, and be applicable to, the work comprehended under the foregoing heads, taken conjointly; and to settle a question that has been made a subject of dispute, an exact average has been made of the actual cost on each branch of the work upon this line, and the following result has been obtained:

* A stove pipe continued from the top to the bottom of each shaft, with a small furnace erected over its summit, would ventilate the shaft effectually.

	D. C. M.
Average price of earth, per cubic yard - - -	00 07 1
rock, do - - -	00 39 7
embankment - - -	00 10 2
wall, per perch - - -	00 52 5
road and farm bridges - - -	145 00 0
fencing canal, by the perch, with posts and boards - - - -	00 75 0
locks, per foot lift, complete - -	578 50 0

The contract prices (undoubtedly less than the actual cost) of the like work on the eastern section of the Pennsylvania canal, running through a country much resembling the valley of the Potomac, to which it is parallel, will be seen in the subjoined synopsis, by Mr. James Clarke, superintendent of the Juniata division of that canal, submitted to the Board of Commissioners, of which he was a member, cotemporaneously with the preceding report of General Abner Lacock.

A TABLE

EXHIBITING the average prices at which the various kinds of work were taken, at the several lettings, on the Juniata division of the Pennsylvania Canal.

Date of the lettings.	No. of sections let.	No. of proposals for work.	AVERAGE RATE AT WHICH THE WORK WAS GIVEN OUT.									
			Excavation.	Embankment.	Puddling.	Solid rock.	Slate rock.	Hard-pan.	Vertical wall.	Outside slope wall.	Inside slope wall.	Grubbing and clearing.
			Cents per cubic yard.						Cents pr perch of 25 cub. ft.		Cts. pr. sq. yd.	
1827												
Aug. 15	35	724	9	$13\frac{1}{2}$	$18\frac{1}{2}$	$42\frac{1}{4}$	$24\frac{1}{4}$	19	39	49	13	$170
29	28	652	$8\frac{1}{2}$	$12\frac{1}{2}$	$16\frac{3}{4}$	$42\frac{3}{4}$	$22\frac{3}{4}$	$17\frac{1}{4}$	$42\frac{3}{4}$	$45\frac{1}{4}$	$12\frac{1}{2}$	76
Sept. 12	28	562	$8\frac{3}{4}$	13	$15\frac{1}{2}$	$43\frac{1}{2}$	$23\frac{1}{2}$	$17\frac{1}{4}$	45	$50\frac{1}{2}$	$12\frac{1}{2}$	160
Aver. of 91 sections			$8\frac{3}{4}$	13	$16\frac{1}{2}$	$42\frac{3}{4}$	$23\frac{1}{2}$	18	$42\frac{1}{4}$	$48\frac{1}{4}$	$12\frac{5}{8}$	$135\frac{1}{3}$

Conclusion of the appendix to the memorial of the Chesapeake and Ohio Canal Company.

From the facts and reasoning in the preceding part of this appendix, which has been unavoidably swelled to a voluminous size, the following deductions must be apparent:

1st. That the actual cost of any canal or railroad must depend on the plan adopted for each work, and the character of the ground over which it is conducted, both as to the quality of its soil or excavated materials, and the regularity, or inclination of its surface.

2d. That the prime cost of the best constructed railroad, of two tracks only, passing over the most favorable ground, must ever greatly exceed the prime cost of the best constructed canal, of ordinary dimensions, passing over ground equally favorable for this species of improvement.

3d. That the best constructed railroads, of two tracks, in Europe or America, and there are none, in either country, as yet, with more than two, exceed, in their original cost, the best constructed canals in America, of ordinary dimensions.

4th. That the Baltimore and Ohio Railroad Co. acknowledged, by the last annual report of its President and Directors, to be as yet imperfectly made for two-thirds of its extent below the Point of Rocks, and having but two tracks, will cost, per mile, nearly or quite as much, and if its obvious defects be hereafter supplied, probably more than the Chesapeake and Ohio canal, which, when done, will be the largest in the world; and, in construction, inferior to none.

5th. That the actual cost of transportation, for commodities, on the only railroad in England, of two tracks, on stone sills, fitted for the exchange of commodities between its extremes, exceeds the actual cost of transportation on any of the canals of ordinary dimensions in the United States, in the ratio of near or quite three to one, and this, whether the propelling power be animal labor, or steam.

6th. That the cost of transportation on the first and best constructed division of the Baltimore and Ohio railroad, a division, about 13 miles long, which has cost $60,000 a mile, has not been reported by the President and Directors of that company, but probably exceeds the cost of transportation on the Liverpool and Manchester railroad, and is *thrice as great*, as the cost of transportation on the Chesapeake and Ohio canal.

7th. That the relative cost of keeping up, by annual repairs, the *fixed capital* vested in the construction of railroads, and their necessary appurtenances, and *that* of canals, has not been, as yet, determined by actual experience for a series of years; but must prove to be greatly in favor of canals, so constructed, as to have no perishable structures about them, except the wood of the lock gates, and certain parts of the houses of their attendants.

8th. And hence it follows, that where great velocity is not required for the transportation of the commodities of a country, as in one, the chief commerce of which, consists of the rude productions of its forests, mines, and agriculture, canals furnish much more valuable channels of trade, than railroads.

9th. But if rapid motion be desired, such have been the late discoveries made in propelling passage boats on the canals in Scotland, that a rational and well grounded hope may be indulged, of approximating the speed of travelling on canals, very near to the useful or practical velocity on the best constructed railroads of two or more tracks.

10th. There will remain, then, to counterbalance all these considerations in favor of canals, having an adequate supply of water, but one advantage in favor of railroads of any number of tracks, that of being unobstructed by ice, during that part of each winter, in which the canal may be frozen, so deep, as to be innavigable. But to this objection it may be replied, that many winters, as far north as the valley of the Potomac, like that of 1827 and 1828, afford no ice, at any time, of the thickness of three inches; and none are so intensely severe as to pass without occasional thaws.

11th. To counterbalance this disadvantage, snow in winter, and dust in summer, will be more injurious to railroads, than to canals. A remedy for

this last cause of objection, is purchased, as we have seen, on the Liverpool and Manchester railroad, at a heavy cost of labor. In a thinly peopled country, in passing successive ranges of inaccessible as well as lofty mountains, beneath precipices of rocks extending for miles together, the removal of drifts of snow, in winter, would be attended with still greater expense, and in snow storms or ice sleets of many hours, or several days' duration, would be nearly impracticable.

12th. The freezing of the water in a canal, is then, the sole consideration operating in the comparison unsettled between canals and railroads, to the prejudice of the former.

And on this subject, there yet remains to be stated, some facts that are not unworthy of consideration.

On the 1st of January, 1831, twelve members of the House of Representatives ascended the first twenty miles of the Chesapeake and Ohio canal, in a commodious packet boat, drawn by three horses amidst floating ice of three inches thickness, broken only the day before. It was broken by a flat bottomed boat, of the value of six dollars, commonly called a gondola; on board of which, were 248 barrels of flour, drawn by two horses, guided by a lad of fourteen years of age, whose father received three dollars for the labor of his son and houses, who descended twelve miles, and returned the same day. The boat was protected from being cut by the ice, by two green cut poles having their stump ends attached to the bottom of it, and brought together at the other ends, and fastened to the tow-rope. As it proceeded, it pressed the ice down, and made its way through it by crushing it to pieces, so that the gondola received no injury. And if the ice on the surface of the canal, when three inches thick, can be overcome with such facility, by means so rude and simple, a very short period, only, of suspended navigation, in each year, remains to be remedied by future invention.

The celebrated civil engineer, to whom the world owes so much, and whom America, his country, has so imperfectly rewarded, the late Robert Fulton, always believed that it would be very easy to construct a boat capable of freeing the navigation of canals and rivers from the obstruction of ice in winter.

In the winter of 1827 and 1828, there was not ice enough, after the month of November, 1827, on the rivers of Virginia, to fill an ice house; and the ice consumed in the southern cities on navigable water, in the ensuing summer, was imported from New England. In the latitude of the Potomac, therefore, the possibility, whenever an active commerce shall require it, of removing the obstruction of ice, on a broad canal, cannot be doubted. And with this confident expectation, the memorialists close the long protracted appeal which they have felt it their duty to make to the representatives of the American people, in behalf of a national enterprize which owes its existence to their wisdom and patriotism, and which, if steadily prosecuted, on the plan on which it has been successfully begun and faithfully continued, will be completed in a few years, and remain, ever after, the proudest monument of that freedom and independence which gave it birth.

ADDITIONAL DOCUMENTS.

A description of the plan, and a statement of the cost, of the Union Canal of Pennsylvania.

The Union Canal Company of Pennsylvania connects the Susquehannah at Middletown, nine miles below Harrisburg, with the Schuylkill, three miles above the head of the Girard canal, two miles below Reading, and about fifty-seven miles above Philadelphia.

Its length is 80 miles, exclusive of a navigable feeder on the Swatara, hereafter mentioned.

Its works comprehend a tunnel of 243 yards in length, 18 feet wide, and fourteen feet in height, two summit reservoirs, containing 12 millions of cubic feet of water, one of them covering 27, and the other 8 acres; two steam engines of 100 horse power each, and three water wheels for feeding the canal by pumping; two dams, one across the Schuylkill, near Reading, and the other across the Swatara, below Hummelstown; 43 waste wiers; 49 culverts; 135 bridges; 12 small and two large aqueducts: the latter are over the Swatara, one 276 feet, the other 175 in length; two guard locks of wood, 92 locks of cut stone, and 14 miles of protection walls of stone.

The Swatara feeder, which is, in fact, a branch canal, is 24 miles in length, including the great reservoir, formed by a dam 40 feet high, and covering near 1,000 acres of surface, extending the navigation to the basins at Pine Grove. A railroad of about four miles in length has also been constructed, commencing at the basins in Pine Grove, and extending to the neighborhood of the coal mines, with a rise of about 130 feet.

The works, and especially the numerous aqueducts and locks, have the reputation of being well constructed.

On the eastern division of the Union canal, there are—
37 miles and 61 chains of canal,
$3\frac{42}{80}$ " of towing path,
54 locks and two guard locks,
311 feet of descent.

On the western division—
$33\frac{4}{80}$ miles of canal,
$\frac{6}{80}$ towing path,
37 locks to the Pennsylvania canal,
$192\frac{1}{2}$ feet of descent,
2 locks of wood at Middletown, near the mouth of the Swatara; descent 16 feet.

The summit level, which is planked, bottom and sides, is $6\frac{78}{80}$ miles in length.

Width of canal at bottom, - -	24 feet,	
" " surface of water, -	36 "	
Depth, - - - - -	4 "	
Depth of summit level, - - -	5 "	
Length of lock chamber, - - -	75 "	
Breadth of do - - -	$8\frac{1}{2}$ "	
Length of boat, - - - -	67 "	
Breadth, out and out, - - -	8 "	3 inches,
Greatest width inside the clear, - -	7 "	6 "

Burthen from 25 to 30 tons, and will draw three feet of water: requires one horse or mule, and the attendance of one man and one boy.

The Swatara feeder is 6¾ miles long, 20 feet in width, four miles long, five feet wide, and two feet deep, descent 7 feet.

Feeder from Kentner's reservoir 1¾ miles long, two feet deep, and 4½ feet wide; descent $4\frac{20}{100}$ feet.

The cost of this canal and railroad has been, exclusive of interest on loans, about two millions of dollars. Its stock consists of 2,500 shares of new, and 738 shares of old stock, at $200 each, which are now selling in the Philadelphia market at 228 to $230 for the former, and 185 to 190 for the latter. The company have loans amounting to $1,430,400, upon which they pay quarterly an interest at the rate of six per cent. per annum.

The tolls of this canal for the two last years, amounted to the following sums: in 1830, $35,133 82; in 1831, 59,137 21; and was derived from the following commodities, viz.

Flour,	Gypsum,	Tobacco,
Wheat and rye,	Fish,	Leather,
Whiskey,	Salt,	Limestone,
Iron,	Merchandise,	Butter,
Coal,	Corn,	Lard,
Lumber,	Flaxseed,	Hemp,
Shingles,	Cloverseed,	Bricks, &c.
Staves,	Cotton,	

The repairs of this canal from the 1st of April, 1828, to January 1, 1831, amounted to $14,737 40.

Repairs for 1831 alone, $2,723, which shows that the amount for repairs is fast decreasing.

It has four collectors of tolls, whose salaries amount, altogether, to about $1,250 per annum; 80 lock tenders and engineers at water works, who receive, on an average, $10,223 25 per annum for their services.

The tolls are collected at the following places, viz. Fair Mount, Reading, Lebanon, and Middletown, and some of the lock tenders are allowed to receive tolls from boats passing a short distance on the line.

RATES OF TOLL UPON THE UNION CANAL—1831.

ARTICLES.	PER TON, &c.	toll per mile.	Toll whole dist'ce.
Ashes, pot and pearl	Per ton of 7 barrels	1½ cts.	$1 20
Bark	cord	1	80
ground	ton	1¼	1 00
Bricks	ton of 500	¾	60
Beef, salted	ton of 8 barrels	1½	1 20
Boards and other sawed stuff	100 feet board measure	1¾	1 00
Barley	ton of 50 bushels	1½	1 20
Butter	ton	1½	1 20
Clay	ton	½	40
Cider	ton of 8 bbls, or 2 hhds	1½	1 20
Coal	ton	¾	60

RATES OF TOLL—Continued.

ARTICLES.	PER TON, &c.	toll per mile.	Toll whole dist'ce.
Corn, Indian	Per ton of 40 bushels	1½	1 20
Earth	ton	½	40
Fish, salted	ton of 7½ bbls or 14 half bbls	1½	1 20
Flour	ton of 10½ barrels	1½	1 20
Furniture, household	ton	2	1 60
Grindstones	ton	1	80
Gypsum	ton	1	80
Hay	ton	1	80
Hoop poles, for barrels	ton of 400	1	80
Do for hhds. and pipes	ton of 200		
Heading for do	ton of 400		
Do for barrels	ton of 500		
Iron, bar, blooms, or wrought	ton	1¼	1 00
castings	ton	1¼	1 00
ore	ton	½	40
pig	ton	1	80
Lard	ton	1½	1 20
Lime	ton of 28 bushels	¾	60
Limestone	ton	½	40
Manure	ton	½	40
Marble, unwrought	ton	¾	60
manufactured	ton	2	1 60
Merchandise	ton	2	1 60
Mill stones and French burrs	ton	1¼	1 00
Oats	ton of 80 bushels	1½	1 20
Oysters	ton of 4,000	2	1 60
Pork, salted	ton of 8 barrels	1½	1 20
Posts, and rails, split	100	1	80
Plastering lath, 3 feet long	50 bundles, or 5,000 to the ton	1½	1 20
Rye	ton of 40 bushels	1½	1 20
Rosin	ton of 8 barrels	2	1 60
Salt, fine	ton of 45 bushels	2	1 60
coarse	ton of 32 bushels		
Seed, clover	ton of 40 bushels	1½	1 20
flax			
of all other kinds			
Shingles	thousand	¾	60
Straw	ton	½	40
Staves, for pipes	ton of 400	1	80
for hogsheads	ton of 500		
for barrels	ton of 600		
Stone	ton of 4-5ths of a perch	½	40
Tar	ton of 7 barrels	2	1 60
Timber, round and square	90 solid feet	1¼	1 00
Wheat	ton of 40 bushels	1½	1 20

RATES OF TOLL—Continued.

Whiskey, and other domestic distilled spirits - - -	Per ton of 2 hhds. or 8 bbls.	1¾	1 40
Window glass - - -	ton of 2,800 feet -	2	1 60
Wood - - - - - -	cord - - - - -	1	80
On all articles not enumerated, passing eastward - -	ton - - - - -	1½	1 20
On all articles not enumerated, passing westward - -	ton - - - - -	2	1 60
On passing boats - - -	mile - - - - -	20	16 00
On boats used for transportation, carrying over 5 tons -	mile - - - - -	2	1 60
On boats, if empty, or carrying not more than 5 tons, besides the toll on cargo - -	mile - - - - -	4	3 20
For passing the outlet locks at Middletown (except such boats as have come, or are going immediately on the Union canal):			
On every loaded boat - -	- - - - -	-	75
On every empty boat - -	- - - - -	-	50

STATEMENT of the Tonnage which passed the Union Canal, from the first of November, 1830, *to November* 1*st*, 1831.

ARTICLES.	QUANTITY.	WEIGHING TONS.
Flour - - - - -	74,905 barrels -	7,133 16 0 0
Wheat and rye - - -	257,565 bushels -	6,439 3 2 0
Whiskey - - - -	12,763 barrels -	1,595 7 2 0
Iron - - - - -	- - - - - -	5,110 15 3 14
Coal (bituminous) - -	85,053 bushels -	2,835 2 3 0
Lumber - - - - -	13,303,000 feet - -	13,303 1 1 0
Shingles - - - -	6,292,000 - - -	3,146 5 2 0
Staves - - - - -	- - - - - -	83 0 3 0
Gypsum - - - -	- - - - - -	6,996 1 2 0
Fish - - - - -	12,263 barrels -	1,635 2 1 7
Salt - - - - -	61,920 bushels -	1,548 8 3 23
Merchandise - - -	- - - - - -	6,389 6 3 0
Sundries, consisting of corn, flaxseed, clover seed, cotton, tobacco, leather, limestone, butter, lard, hemp, bricks, &c. - - -	- - - - - -	3,755 4 0 22
Total amount of tonnage -	- - - - - -	59,970 16 2 10

Amount of tolls received during the same period, $59,137 21.

Extract from a speech of Mr. Maynard, delivered February 25, 1832, in the Senate of New York, showing how small a portion of the revenue of the Erie canal is derived from passengers.

The report of the canal board, said Mr. Maynard, states the amount of tolls received on passengers in packet boats during the last year, at about 8,000 dollars; but that they were not able to state the precise amount received on passengers in other boats. They had, however, given some data from which a calculation could be made, and from which he had made an estimate, though it was difficult to ascertain the precise sum. His estimate was, that the tolls on packet boats amounted to 12,000 dollars, to which, being added the 8,000 dollars received on passengers, made the whole amount received on these boats and their passengers, 20,000 dollars. The amount of line boats, he estimated at 28,000, but would set it down at 30,000. The whole amount would then be 50,000 received annually from this source; and it remained to be considered how much would be withdrawn from the canal, should this road be constructed.* Mr. M. conceded that all the travelling in packet boats would be withdrawn from the canal if this road should be constructed, but denied that any would be withdrawn from the line or freight boats. Those who travelled in them consisted almost wholly of emigrants from the eastern States to the western country, and emigrants from Europe, English, Irish, Swiss, Germans, Mancks, and Welsh, having the same destination, none of whom would ever travel on the railroad. They did not desire expedition, but sought a slow, safe, and *economical mode of conveyance*, and there was *none more economical*, than in those boats, where an adult passenger could be carried one hundred miles, for two dollars and a half, including his board. Mr. M. believed it a fair estimate that $50,000 annually, for tolls from this source, was all that would ever be realized. Now, said Mr. M., will the State retain all this, if the railroad be not made? He thought not. A report made by the canal board to the Senate, in 1830, stated that these packet boats should be driven from the canal, sooner or later. And a report from the Committee on Canals of the Senate of the same year, stated that it was a convenient mode of travelling and transporting valetudinarians, but that they had done *more injury to the canal*, than all the tolls ever paid by them, into the canal fund, had benefitted that fund, and that it would be better to stop them at once. Still they had been permitted to remain. The proprietors, themselves, believed that the time was not far distant when they would be driven from the canal."

RAILROAD FROM ALBANY TO SCHENECTADY.

Report of the President and Secretary of the Mohawk and Hudson Railroad Company to the House of Assembly of the State of New York.

NEW YORK, *January* 26, 1832

The undersigned, the President and Secretary of the Mohawk and Hudson Railroad Company, beg leave, in compliance with the resolution of the honorable House of Assembly of the 21st instant, respectfully to report:

1. That it appears by the books of the treasurer of the said company, that the sum of four hundred and eighty three thousand two hundred and fifteen dollars and forty-six cents, (483,215,46) has been actually paid and disbursed in the construction of said railroad,† up to the present date.

*A road parallel to the canal.

† This railroad is but sixteen miles long.

2. That, from the estimates of the engineers of the said company, and from an examination recently made of the contracts not yet completed, it appears, that, to complete a double railroad within the limits prescribed by the act incorporating the Mohawk and Hudson Railroad Company, with the necessary machinery, carriages, and appurtenances, will require the expenditure of the additional sum of one hundred and fifty-six thousand six hundred and ninety-three dollars and eighty-seven cents, ($156,693.87.)

3. That the precise route of the branch railroad contemplated by the said company, has not yet been determined upon, nor any accurate examination made of the ground. The undersigned are therefore unable to state with any certainty what the expense of constructing the branch railroad will amount to, but they are inclined to believe that it will not vary materially from the sum of one hundred thousand dollars, ($100,000,) being the amount the said company has (in the joint application made with the Albany and Schenectady Turnpike Company, to the honorable the Legislature of the State,) prayed may be added to its capital stock for the express purpose of making said branch.

The undersigned beg leave respectfully to add, that, until the railroad be completed, the details of the items on which the expenditures above recited have accrued, are necessarily kept in the offices of the engineers of the company, in the cities of Albany and Schenectady. They have therefore judged it to be more respectful to the honorable House over whose deliberations you preside, to communicate forthwith the information immediately within their reach, complying, as it fully does, with the terms of the resolution, than to delay for the purpose of presenting their report in a detailed form, specifying the exact objects to which the expenditures have been directed. They beg leave, however, to tender, on behalf of the board of directors of the Mohawk and Hudson Railroad Company, any additional information their archives may contain, and this not as a matter of mere duty, but in the belief that the experience of this company may be of value in the investigation of the many projects of similar character now pending before the Legislature.

All which is respectfully submitted.

STEPHEN VAN RENSSELAER,
President of the Mohawk and Hudson Railroad Company.
JAS. RENWICK,
Secretary of the Mohawk and Hudson Railroad Company.

RAILROAD FROM NEWCASTLE TO FRENCHTOWN,

IN THE STATE OF DELAWARE.

The length of the road from centre of Front street, in Newcastle, to the wharf, on Elk river, at Frenchtown, is 86,910 feet, or $16\frac{46}{100}$ miles.

Note.—The length of a straight line, connecting the eastern and western terminations of the road, is 84,332 feet, or $15\frac{97}{100}$ miles.

This road is composed of 6 curves and 6 straight lines, of which the curves amount to 27,240 feet, or $5\frac{16}{100}$ miles.

And the straight lines amount to 59,670 feet, or $11\frac{3}{10}$ miles.

The radius of the least curve is 10,560 feet, or 2 miles. The deflection on 100 feet of which, is $\frac{119}{1000}$ of a foot, or $1\frac{4}{10}$ inches.

The radius of the greatest curve is 20,000 feet, or $3\frac{79}{100}$ miles. The deflection on 100 feet of which, is 0.062 of a foot, or $\frac{3}{4}$ of an inch.

The road bed is graded 26 feet wide, exclusive of side drains; average width, including drains, about 35 feet.

The whole amount of excavation, exclusive of those drains, is 496,000 cubic yards.

And the whole amount of embankment is 423,000 cubic yards.

There are 4 bridges or viaducts, and 29 culverts of stone masonry.

The deepest excavation is $36\frac{3}{10}$ feet.

The highest embankment $23\frac{9}{10}$ feet.

The greatest ascent or descent on the road is 29 feet to a mile. This grade is only for about $\frac{7}{10}$ of a mile next to the western termination of the road.

The greatest ascent or descent on any other part of the road, is $16\frac{8}{10}$ feet per mile.

The cost of graduation, including the cutting of drains, filling wharves for landings at New Castle and Frenchtown; and also horse track within the rails, and exclusive of masonry, - - - - - $185,000

Or, per mile, about, - - - - - - 11,000

The cost of bridges and culverts, (materials and workmanship) about 16,000

Or, per mile, nearly, - - - - - 1,000

A single track of railroad is laid down with seven sidelings for turn-outs of 500 feet in length each.

On about 9 miles of the track, the rails are laid upon blocks of granite, containing each about 2 cubic feet, placed at the distance of 3 feet apart from centre to centre, and well bedded on sand or gravel.

The string pieces upon which the iron bars, or rails, are laid, are of Georgia yellow heart pine, 6 inches square, and are fastened to the blocks by cast iron knees, two to each stone.

The iron rails (or bars) are $2\frac{1}{4}$ inches wide, and $\frac{5}{8}$ of an inch thick.

On the remainder of the track, say $7\frac{1}{2}$ miles, the string pieces and rails of the above description, are supported on wood foundations; the greater portion of which is of the description following, viz.

Hemlock plank, averaging about 10 inches wide and 4 inches thick, are laid lengthwise along the track on both sides, in the bottom, resting on sand or gravel. On this foundation, cross sleepers of white oak, about $7\frac{1}{2}$ feet long and eight inches in diameter, are laid 3 feet apart from centre to centre, which are spiked down to the plank. On these sleepers, the string pieces rest, and are secured to them in the usual manner.

The cost of materials and workmanship for the part of the track with stone foundations, per mile, - - - - - - $6,300 00

Cost of the materials and workmanship for the part of track with wood foundation, per mile, - - - - - - $4,440 00

The total cost of the road, including land, fencing, damages, wharves or landings, expense of engineer department, pay of officers, &c., and exclusive of depots and other buildings not completed, - - $365,000 00

Or, per mile, about, - - - - - - 22,000 00

New Castle, *April 7th*, 1832.

Dear Sir: The preceding answers to your inquiries relative to our railroad, are made out as exhibiting, as near as practicable, the information desired. As we have not yet entirely completed the road, we cannot present

a statement of expenditure embracing the full amount, with certainty. As to the expense of transportation, we have not yet had time to ascertain what it will be.

Yours, respectfully, &c.,

KENSEY JOHNS, Jr.

Hon. Chas. F. Mercer.

LIVERPOOL AND MANCHESTER RAILROAD.

From Gore's Liverpool General Advertiser.

Published prior to the commencement of the road.

"PROPOSED RAILROAD.

"Mr. Stephenson, of Newcastle-upon-Tyne, has laid down the line between Liverpool and Manchester; the distance is 33 1-16 miles. The surveys are nearly completed, and the committee entertain not the least doubt of being ready for the next session of Parliament. Independent of the great benefit which the commercial interest will derive from the project, which, both as regards time and cheapness, will prove most important, the landed interest in the vicinity of the line, will also derive very great benefit. The communication will be so cheap and rapid, that the distance from a market for produce, or for the supply of manure, will amount to very little. New collieries will be opened, and coals will be much reduced in price. The public, in general, entertain wrong impressions respecting railways: they never hear them mentioned, without referring to such as are seen in the neighborhood of coal pits and stone quarries. But such improvements have taken place, that they are no longer the same thing; besides which, a railway, without a locomotive engine, is something like a cart without a horse, a trade without profit, or a canal without water."

From the Courier.

RAILROADS AND LOCOMOTIVE STEAM ENGINES.

The public, generally, are but very little aware of the uses to which railroads are about to be applied. The following information, therefore, will, we trust, be acceptable to our readers.

Hitherto, railroads have been used for very limited purposes, and whenever they are spoken of, it is in connection with coal pits and stone quarries; but they are now about to be applied for the purpose of conveying merchandise over very extended lines of country, and thus they are becoming an object of great national interest.

Railroads, as hitherto worked by horses, possess very little, if any, advantage over canals; but railroads worked by the locomotive steam engine, have so decided a superiority, both as regards time and expense, that there can be no question but they will be generally adopted, wherever a new line of conveyance has become necessary, either from an increased trade, or from the exorbitant demands of canal proprietors.

By the locomotive engine, fifty tons of goods may be conveyed by a ten horse power engine on a level road, at the rate of six miles an hour, and lighter weights at a proportioned increase of speed. Carriages for the conveyance of passengers, at the rate of 12 or 14 miles per hour. For canals, it is necessary to have a dead level, but not so for railroads; an engine will work goods over an elevation of one-eighth of an inch to the yard. Where

the ascent or descent is rapid, and cannot be counteracted by cuttings or embankments, recourse must be had to permanent engines and inclined planes, just as recourse is had to locks for canals: but here again the railroad system has a great advantage; the inclined plane causes no delay, while locking creates a great deal.

Two acts of Parliament have already been obtained, namely, the Stockton and Darlington act, and the Moreton act. On these lines, which exceed thirty miles each, it is intended to adopt the locomotive engine, and they will both be very soon ready for the conveyance of goods. There are also three or four other railroads projected.

Two years ago, several gentlemen in Liverpool and Manchester subscribed to obtain a survey of a line between those two towns. It was accomplished and found practicable. From various causes, the prosecution of the plan was delayed; but, *a few months since*, it was undertaken with great spirit. A deputation from both towns was appointed to inspect the railroads and locomotive engines of the north. They inspected the Stockton and Darlington line, and inquired minutely into its cost; they witnessed the engines working on the Helton railroad, near Sunderland, and made a most favorable report. The committee immediately appointed Mr. George Stephenson, of Newcastle-upon-Tyne, their engineer, who has since surveyed and adopted a new line. Its length is 33 and 1-16th miles, and the greatest ascent or descent is only 1-16th of an inch to the yard. The distance by the high road is 36 miles, and by the canals and river 50 miles. The shares appropriated to Liverpool and Manchester, have all been disposed of, but the committee have a small number placed in their hands, to be distributed as they may deem proper. Application for an act will be made next session of Parliament; *the cost is estimated at about* £300,000.* Mr. Stephenson has also laid down a line between Birmingham and Liverpool, of which report speaks most favorably; and the Birmingham committee will also go to Parliament next session.

Extract from a late Report of the Directors of the Liverpool and Manchester railway.

LIVERPOOL, 28*th September*, 1831.

The directors, at thegeneral meeting held in this place exactly six months ago, laid before the proprietors the result of the working of the railway for 3½ months, up to the 31st December, 1830.

They have now to report the result of six months' operations, from the 1st January, to the 30th June last. During that period, the company's business, both in merchandise and passengers, has been gradually and steadily on the increase.

The tonnage of merchandise conveyed between Liverpool and Manchester, for the six months, amounts to - -	35,865 tons.
Between Liverpool and the Bolton junction, - -	6,827 "
	42,692 "
Coals, principally from the Huyton collieries, a distance of five miles from Liverpool, - - - - - -	2,899 "
Number of passengers booked at the company's offices,	188,726

* About one-third of its actual cost.

The gross receipts on this traffic are as follows:

On passengers, - - - - - - -	£43,600 7 5
merchandise, - - - - - - -	21,875 0 1
coal, - - - - - - - - -	218 6 2
	£65,693 13 8

Amounting to 4*s.* 7½*d.* each, per passenger booked, and 10*s.* 3*d.* per ton of merchandise conveyed.

The disbursements upon the same traffic, amount to	£35,379 3 10
Or, belonging to the coaching department, - -	£19,099 16 5
to merchandise, &c. - - - - -	16,279 7 5
	£35,379 3 10

These disbursements, the directors, from the classification of their accounts, are enabled to apportion to the different departments, and under different heads of expenditure, as follows:

	Per passenger booked.		Per ton of merchandise.		Coaching department.			Merchandise department.			Totals.		
	s.	d.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
Disbursements exclusively in the coaching department, consisting of porterage, salaries, repairs, &c., including 2½d per passenger for Omnibussus - -	0	7¾	-		6146	11	0	-			6146	11	0
Disbursements exclusively in the merchandise department, consisting of porterage, salaries, cartages, &c.	-		3	10¾	-			8306	3	11	8306	3	11
Locomotive power account, proportioned according to the number of trips of 30 miles, in each department respectively, comprising repairs of engines, wages, coke, &c., including £33 17s. 3d. for conveyance of coal as back carriage -	0	5¾	1	8¾	4505	18	10	3692	14	5	8198	13	3
Sundry disbursements proportioned according to the receipts in each department, conisting of police establishment, general office establishment, maintenance of way, rates, taxes, &c. including £2910 0s. 3d. for interest of money borrowed - - -	0	10¾	1	11½	8447	6	7	4280	9	1	12727	15	8
Total disbursements	2	0½	7	7	19099	16	5	16279	7	5	35379	3	10
Amount of profit -	2	7	2	8	24500	11	0	5813	18	10	30314	9	10
Gross receipts as per above statement - -	4	7½	10	3	43600	7	5	22093	6	3	65693	13	8

"The directors have found the disbursements consider ably heavier than they anticipated, especially that portion of them belonging to the merchandise department. It may be proper, however, to remark, that the quantity of merchandise conveyed is comparatively small, the business at the present moment being on a much larger scale than the average business of the six months included in this statement, while the expense of carriage will not keep pace in the same ratio with the increase of the tonnage. On the other hand, with reference to the present result, *as no allowance is made for wear of materials,* (except what is comprised in actual repairs,) the first six months will have some advantage over succeeding periods, from the wagons, &c. being new to begin with. The above statement of receipts and disbursements has reference, of course, exclusively to the traffic on the line. The sum raised by the creation of new quarter shares, being appropriated altogether to the building of warehouses, wharfs and sheds, the purchase of engines, cranes and wagons, and, generally, to the completion of the road and the works."

The following extracts are from a work entitled "Remarks on Canal Navigation, by William Fairbairn, Engineer, published in London in 1831."

Since the first formation of canals in this country, there have been very few attempts made to improve the construction of vessels adapted to an inland navigation. The passage boats of the present day are nearly the same as they were fifty years ago; and little, or rather no improvement has taken place in the heavier description of vessels for the conveyance of goods, since the period of their first introduction. Probably this might have gone on in the same state of supposed perfection, had not the introduction of railways, which are now in progress, occasioned such a sensation in the country.

From the first commencement of canal navigation up to the present time, the average speed of conveyance has never exceeded four miles and a half per hour on passage boats, and two miles and a half on heavy flats.—This seems to have been the maximum velocity; and it was taken as an established rule, that boats could not be conveyed along canals, at a greater rate, without incurring loss, and a considerable increase in the cost of transit.

My particular attention was, in the month of January last, drawn to these very obvious defects in canal navigation, by Mr. Thomas Grahame, of Glasgow, who had, for some years before, been giving a great deal of attention to the improvements on canal navigation, by the introduction of steam as a moving power.

Mr. Grahame requested me to give the subject my best consideration, in order to see how far such a light description of boat, having a small draught of water, would be applicable to quick speed, and whether steam could not advantageously used as a propelling power on canals.

The fulfilment of Mr. Grahame's instructions, was surrounded with difficulties of no ordinary character; such as the resistance of fluids to moving bodies, the agitation of the surface, and the consequent danger to the banks of the canal, arising from the surge or wave, occasioned by vessels propelled at a quick rate. These and many other obstacles presented themselves. Not the least, however, was the power requisite to raise, and maintain an accelerated velocity in bodies opposed by such a powerful resistance. It also appeared questionable, whether the power required was not more than commensurate to the advantage gained by the proposed increase of speed.

In Holland, the passage boats travel at the rate of six English miles per hour; and I believe, on some lines of navigation, it is no uncommon occurrence for boats to move even at a greater velocity. In this country we seldom, if ever exceed five miles; and I am inclined to think, that four miles and a half per hour is the greatest and most advantageous speed we have yet attained.

The source, to which I looked for improvements, was steam; a judicious employment of which might remove the difficulties, and furnish power sufficient to overcome all obstructions. Steam engines of the usual construction, from their great weight, seemed but indifferently calculated for propelling boats on canals, as the draught of water would be increased, and greater risk of injury to the banks would be the consequence. Engines on the locomotive principle, from their portability and lightness, appeared best fitted for the purpose, and best calculated to give the requisite force, without materially increasing the weight of the boat, or producing the apprehended injury to the canal banks.

This being a settled point, the next consideration was, how to employ these engines to advantage; how to give perfect security; and, at the same time, how to produce at least a double velocity, without incurring the injurious tendencies already detailed. This was certainly a desideratum more to be wished for than expected. We all know that force must be applied to a body to move it through a fluid; that such force meets with opposition from the resisting fluid; and, that that resistance is stated to increase with the squares of the velocities. These points being taken for granted, it will be seen that there was much to contend with in surmounting such formidable obstacles.

Taking as a datum what has been already stated, that the resistance of fluids to passing bodies is as the squares of the velocities, I had then to calculate what power would be requisite to give the increased speed to boats of different tonnage, and to produce a force equal to the resistance as laid down by scientific men, who have treated on this subject.

I was prevented pursuing with Mr. Grahame the inquiries on the subject of canal steam navigation, by business, which compelled my own and his attendance in London for the greatest part of last spring.

While we were engaged there, an experiment was made by William Houstoun, esquire, of Johnstone, on the Ardrossan canal; the results of which were communicated to me, and which at once seemed to make rapid motion on a canal infinitely more easy, by doing away with the danger of injury to the banks, by wave or surge consequent on quick motion through a comparatively narrow body of water.

The experiment, made by Mr. Houstoun, consisted in the introduction into the canal of a common gig boat, in which ten or twelve passengers were seated; after which the boat was drawn through the canal by a single track horse, at the rate of twelve miles an hour, without either wave or surge.—Unluckily no printed account of this experiment was ever published, or it would be proper here to insert it.

In pursuance of this first experiment, Mr. Grahame, on his return to Glasgow, proposed to have it renewed on the Forth and Clyde canal; but, on examining the gig boat, with which the experiment was made, he found it was so light and unsteady, as to give an idea of want of safety to passengers; and he was afraid that if a larger and stronger boat were built, it might have the same faults; and, at all events, it would be so crank as to be unfitted for the application of steam power.

To avoid these difficulties, and to obtain steadiness and security on the water, the idea of a twin boat, of the description of the single gig boat, suggested itself to Mr. Grahame, and, to prove the suggestion, an experiment was made, of which the following account appeared in the various newspapers of the day:

"*Experiments on the velocity of light boats on a canal.*

"The following experiments prove, most satisfactorily, that a very high rate of speed may be obtained and kept up on canals for the conveyance of passengers and luggage, at a very trifling expense, and without injury to the banks, by the agitation of the water.

"About six weeks ago, at the suggestion of one of the committee of management of the Ardrossan canal, a gig, such as is used in rowing matches, was hired, and being launched on that canal, it was found that she could be drawn along the canal at the rate of twelve miles per hour. On this occasion, eight persons and the steersman were in the gig, when a distance of two miles was accomplished with one horse in ten minutes, without any surge or agitation of the water, so as to injure the banks.

"As, from the necessary lightness of the above description of boats, they are very crank or unsteady in the water, and easily moved from side to side, the following experiment, to try the effect of a double or twin boat, was made on the Forth and Clyde canal, on Thursday last.

"Two gigs were hired, but unluckily two of the same size could not be procured. The one gig was thirty-three feet in length, and four feet two inches in breadth, at the broadest point. The other was thirty feet in length, and four feet in breadth, at the broadest. They were strongly fastened together by cross planks, and otherwise secured, so as to prevent any yielding. At the point in front where the respective keels cut the water, the distance was exactly four feet nine inches, measuring along the surface of the water, while the distance about the centre of the boats, measuring on the surface of the water, was only 18 inches. Between the prows of the two boats, a pole was fixed or inserted in one of the connecting boards, three feet in height, and to the top of which a towing line was attached, which, unfortunately, however, was too short and too thick. The horses, also, used for the trial, could not, except at a gallop, go at a pace above eight miles an hour. The boats proceeded from the old basin on the Forth and Clyde canal, and went out three miles and a half towards Kirkintilloch. The first mile, including the passage of a bridge, where the line was thrown off, and the time lost in consequence of the rope yielding over the top of the pole, and being thus disengaged from the boat, was about seven minutes; and the surge was not greater than that raised by the common canal passage boat. Even at the curves, where, from the shortness of the line, the boats were obliged to come close into shore, the water never receded under the bottom of the stone facing. The next two miles were done, each in the course of six minutes, but the pace was very irregular, owing to the necessity of keeping the horse at a gallop. In returning the three miles and a half homewards, no regular account was kept of the first two miles and a half; but the last mile was done in five minutes, including the time lost at the passage of a drawbridge, where the line had to be thrown off, and the passing of a large sloop, where the speed was obliged to be slackened. In the last mile, the surge occasioned by the passage of the boat through the canal, was less than when moving at a lower velocity, and could not, by possibility, injure the banks in the least degree, where lined with stone; nor would

the surge have injured the banks more, though unlined with stone, than the ordinary passage boats moving a little upwards of five miles an hour. Mr. Hunter, the proprietor of the boats, stated his belief that this would be the result of a high rate of speed before it was tried; but whether the decrease of wave arose from the steersman of the boats having become better acquainted with their trim in the canal, or from whatever other cause it arose, their effect was evident to every person on board When passing through the water, there was very little agitation on the outside of the two boats, but the water was frequently raised six and seven inches, and more in the centre parts of the little trough or canal between the boats; so much so, that small portions of it were thrown over into the boats. The water, after passing the straight parts of the trough or canal between the boats, came out with great rapidity behind, and went off in a small column or wave, sometimes five or six inches above the keels or rudders, making towards the banks on each side. The number of people on board the boats, was nine or ten. After this experiment, the larger boat was detached, and two miles out and in on the canal were done at the rate of fifteen miles an hour. One of these miles, where a bridge had to be passed, and in which a loaded vessel was also passed, and where, at the bridge, the line had to be thrown off, and then caught and thrown into the boat, was done in four minutes and a half. In fact the speed seemed only limited by the power of the horses. The surf or surge was very slight with the single boats, even when moving at fifteen miles an hour; but still it bore a much greater proportion to that occasioned by the double boat, considering the very unfair nature of the trial, than could have been imagined. No danger is to be apprehended from the stoppage of the double or single boats, however suddenly, as they brought themselves up almost instantaneously. It is right to explain, in regard to the trial of the single boat, that this trial was made with the same horse that had previously done the experiment in the double boat; otherwise, the time would, no doubt, have been considerably shorter. One horse only was used in drawing, and, for the first two or three miles, it was ridden by the driver, a heavy man, without a saddle.

"There can be no doubt, that, if the above experiment had been made with a properly constructed twin boat, the surge or wave must have been much diminished, if not entirely done away with, while the boat would have been equally steady. We understand that a large passage boat, of a gig-shape, is at present constructing by Mr. Wood, of Port-Glasgow, for the Ardrossan canal, and that it is expected she will perform the voyage between Paisley and Glasgow, in three quarters of an hour, carrying 36 passengers. As this boat is to be single, it has been suggested that any unsteadiness or crankness in the water, may be done away with, by placing around the boat, and a little above the water mark, a hollow copper or iron tube, such as is used in safety boats. In this way, she would at once be brought to a bearing, before yielding much to either side, and, at the same time, the boat would be at once made a safety boat.

"Three different results from the above experiment, are worthy attention: first, the ease with which the boats were brought up or stopped, when moving at a high rate of velocity; second, the little additional labor in drawing, occasioned to the horse when drawing the boat at this high rate, as compared with a low rate of velocity; and, third, the apparent diminution of the surge or agitation in the water, at a high rate of velocity. The best explanation of these matters, is by the supposition, that, at a high rate of velocity, the flat boat rises toward the surface, and skims over instead of cutting the water.

The moment the towing line is slacked of, the boat sinks to her usual depth, and of course brings herself up immediately, owing to the increased resistance of the additional column of water which she must cut. On the other hand, when moving at a high rate, and skimming near the surface of the water, the labor of the horse is diminished in proportion to the diminution of the column of water displaced, and the wave or surge is diminished in a like ratio. The Ardrossan canal is a very small barge canal, fitted for boats of from 25 to 30 tons burthen, while the Forth and Clyde canal is ten feet deep, and of a proportional breadth. The gigs with which the above experiments were made, belonged to Mr. Hunter, boat-builder, Brown street, Glasgow, who fitted up the twin boats for the experiments in the Forth and Clyde canal; and who is, at present, engaged in making the model of a large twin boat, fitted to carry passengers and luggage on the Forth and Clyde canal. Great credit was due to Mr. Hunter for the mode in which the twin boat was fitted up and connected."

The diminution of wave or surge consequent on very rapid motion through the canal, stated to have been observed by Mr. Grahame, the writer of the above account, appeared very anomalous, and contrary to all previous theory, and was, by many persons present at the experiment, considered as *ideal.*

In the month of June afterwards, in consequence of the success of Mr. Houstoun's experiment, a light gig-shaped boat, built by the Ardrossan Canal Company, was launched on that canal, and the following is a detailed account of her first voyage to and from Paisley:

"*First voyage of the Paisley Canal New Passage Boat.*

"Some months ago, by the suggestion of Mr. William Houstoun, of Johnstone, the committee of management of the Ardrossan and Paisley canal were induced to make certain experiments for ascertaining the rate of velocity at which a light gig boat might be propelled along that canal. The experiments were made with a gig rowing boat of about thirty feet in length, constructed by Mr. Hunter, boat-builder, Brown street, Glasgow; and this boat, with ten men on board, was drawn two miles along the Ardrossan or Paisley canal, in the space of less than ten minutes, without raising any surge or commotion on the water—the force employed being one horse, ridden by a canal driver. No account of this trial has ever been given to the public; but it was so satisfactory as to induce the committee of the Ardrossan canal to contract with Mr. Wood, of Port Glasgow, for a gig-shaped passage boat, sixty feet in length, and five feet in breadth, fitted to carry from thirty-six to forty passengers.

"In the month of April last, a number of experiments were made in the Forth and Clyde canal, with two gig boats fixed together, constructed by Mr. Hunter, and thus forming what is called a twin boat. The object of these trials was to ascertain the rate of speed at which vessels might be propelled along that canal, and the effect of a light double or twin boat, in giving that degree of steadiness, which, it was apprehended, would be so much wanting in a light single boat. A statement of these experiments on the Forth and Clyde canal, has already appeared in the newspapers, and the only fact therein mentioned, which it seems necessary to repeat here, is the remarkable circumstance, that the quicker the boats were propelled through the water, the less appearance there was of surge or wave on the sides of the canal. This result, so contrary to every previous theory, was doubted by several of the parties present at these experiments. The surge was, at no

time, and, in no instance, to any extent, and the apparent diminution of it at a high rate of velocity, was supposed to be imaginary. The result of the experiment, however, was so satisfactory, that a twin boat of a gig shape, sixty feet in length, and nine feet broad, is at present building by Mr. Hunter, Brown street, Glasgow, and will be launched in the Forth and Clyde canal in the course of the present month.

"The single gig-shaped passage boat, contracted for by the Ardrossan Canal Committee, was launched at Port Glasgow on Wednesday last, the 2d of June, and she was towed up to the Bromielaw, and thence carried to Port Eglinton the day following; and, on Friday the 4th of June, a trial, of which the following is an account, took place. The boat is sixty feet long, four feet six inches breadth of beam, and drew, on an average, including a deep keel, ten inches when light.

"From the great hurry in which this trial was made, it was done under many disadvantages. None of the canal horses were accustomed to, or able for a continuation to move at any high rate of speed, and a post horse which had never towed a boat, and was quite new to the kind of work or pull necessary on a canal, was the substitute. The hauling rope was too thick. The boat started from Port Eglinton for Paisley, a few minutes after one o'clock, with twenty persons on board, and the distance from Port Eglinton to Paisley, being seven miles, was accomplished in one hour and seven minutes. The greatest speed with which the boat moved during this journey, was at the rate of one mile in nine minutes; and the slowest rate at which any one mile was accomplished, was eleven minutes.

"As the horse was quite unaccustomed to dragging boats, and it was apprehended that it might scare at the canal, and in passing under the narrow bridges, the rider was ordered to start, and proceed the first mile or so at a very moderate pace; but even at this moderate pace, the wave raised in front of the boat was very considerable. A high wave was seen on the canal preceding the boat, about eighty or ninety feet in front, and, in some cases, farther, and causing an overflow at the bridges, and in the narrow parts of the canal. The surge or cutting wave behind the boat was, however, comparatively slight, and, except at the curves, would not have caused much injury to the canal banks. The horse was very much exhausted when he got to Paisley; though by no means so exhausted as he was about the middle of the journey, having sensibly recovered after the first four or five miles.

"As it would have detained the party who came to witness the trial, too long, if they had remained at Paisley till the horse was fed, two post horses were hired there; and, lighter towing lines being attached to the boat, it started again, on its return to Glasgow, with twenty-four persons on board, four of whom were boys, and arrived at Glasgow, a distance of seven miles, in forty-five minutes. Unluckily, one of the horses, the front one, scared very much at the canal, and at the bridges; and two or three stoppages took place in consequence of this horse getting entangled with the ropes. By altering the mode of attaching the rope, and putting the second horse in front, this difficulty was partially got over; and the distance of seven miles was accomplished in forty-five minutes, including in these forty-five minutes the time occupied in disentangling the horses, and changing their positions, and the constant delay occasioned by the horse before mentioned scaring at the canal. The greatest speed attained during the journey, was two miles in eleven minutes. During this voyage, the surge behind was entirely got quit of, even at the curves, where it was reduced to nothing; and there

was no front wave, except at the bridges. It appeared only at the bridges, and just as the boat was about to enter under the bridge, and gradually disappeared as the stern of the boat cleared the bridge. Thequicker the boat went, the more entire was the disappearance of all wave and surge, except where the water escaped in the centre of the canal, and met in two very noisy and rapid currents from each side of the boat at the rudder. This noise and rush of water was so great behind, as to induce persons on board to look round, expecting to see a great wave or surge on the bank of the canal, but on the banks there was hardly a ripple. The two rapid noisy currents seemed to be completely spent and exhausted by the shock of their concourse behind the boat. Here, therefore, there was no room to doubt of the correctness of the reports of the Forth and Clyde canal experiments. It was not merely to be said that the greater the speed the less the surge or wave, but it was demonstrated that, at a high rate of speed, surge and wave were done away with altogether.

"Although, according to all established theory and calculation, as to the force requisite to obtain accelerated speed on water, the two horses from Paisley did more than triple the work of the single horse from Glasgow, supposing they had worked together, while it was evident that almost the whole work was done by one of the two, yet they were both much less fatigued than the single horse. Unluckily, there was no dynamometer attached to the rope, so as to ascertain whether, contrary to all theory, the strain or pull was not equally diminished with the wave, and the tugging labor of the two horses lessened instead of increased, by the accelerated rate at which they drew the boat. There can be no doubt, however, that with one trained horse, properly attached, the distance could be done in a period under forty minutes.

"Contrary to expectation, Mr. Wood's boat was quite steady in the water, and by no means crank. When in the basin at Paisley, seven full grown persons stood on one side of her while she was empty, and could not, with their united weight, bring down that side to within some inches of the water. The keel was, however, very deep and heavy, and is to be altered.

"It may be proper to mention that the Ardrossan canal is, throughout, very narrow; at the bridges and many other places, it is only nine feet broad. It has a great number of turns, and many of them very sudden."

This voyage, at once set at rest all doubts on the subject of the effect of a high velocity with a gig-shaped boat in a canal; and the boat in question has since been regularly plying on the Ardrossan canal, carrying from forty to fifty passengers, between Glasgow, Paisley, and Johnstone; and has fulfilled all the anticipations of the parties for whom she was constructed.

From the above, it will be seen that the question of surge and injury to the banks, so much feared, and so strenuously insisted upon by the parties opposed to improvement, was forever set at rest by the voyage made by the light gig boat, in one of the narrowest canals in Scotland.

The trial of the Paisley boat was speedily followed by a second trial, on the Forth and Clyde and Union canals, of a twin boat built for Mr. Grahame, by Mr. Hunter of Glasgow, to prove, on a large scale, the practicability and advantages of twin boats for canal navigation.

The boat built by Mr. Hunter being launched, an experimental voyage was made to and from Endinburgh. At this voyage I was present, at the request of the Committee of Management of the Forth and Clyde canal, in order to give an opinion as to the practicability of the application of steam power,

to propel, with rapidity, a boat of the twin form. The following is an accurate account of this experimental voyage.

[The account of this voyage will be seen in the extracts already published from the same work.]

The facts detailed in the preceding article seem to establish the principle, that the greater the speed the less the surge; and that a gig-shaped boat, moving at a velocity of nine miles per hour, completely surmounted the surge, and rode over the accumulating swell that, otherwise, would have risen in her front.

It is a curious yet important fact, that a gig-shaped boat, moving at a velocity of from seven to eight miles an hour, produces a considerable swell running longitudinally with the canal, and, by the displacement of water, forms a hollow trough, with a heavy surge fore and aft of the boat, rolling sluggishly along the banks, and, in many cases, washing over the track path, ten or twelve inches deep. Produce, however, an impulse equal to nine miles an hour, or until the boat is impelled at a velocity greater than the undulating motion of the water, and immediately the swell disappears; the boat glides smoothly along the surface, and proceeds with as much apparent ease, as if she were moving at only four or five miles an hour.

Having thus mentioned the peculiar adaptation of the twin boat to high speed, and to the conveyance of passengers, I shall now give the reasons, why a boat constructed with a stern paddle seems best fitted to succeed in a voyage, where the boat, carrying goods and luggage, has to pass from a canal into the open sea, or *vice versa*.

It is quite clear, that, whatever may be the comparative merit of side paddles, such paddles are out of the question in canal navigation; as, independent of their liability to be injured in the locks, and on the banks of the canal, they must contract the bearings of the vessels to which they are attached, and make them of very small burthen. The centre paddle or twin boat principle, in like manner, contracts the bearings of the vessel, and the tunnel in which it works is liable to be choked, whenever the vessel moves from the canal into the sea, in stormy weather.

The stern paddle seems, therefore, the only means for adapting a canal steamboat, both for sea voyages and canal traffic. The Cyclops steamer, formerly mentioned as built for the use of the Forth and Clyde Canal Company, fully confirms this conclusion, and also points out what improvements may be made on boats of this description. I shall here give an account of her first voyage to Alloa, as contained in a letter from Mr. Grahame to myself, in the month of October last:

GLASGOW, *7th October*, 1830.

"MY DEAR SIR: Since I wrote you last, I have been on the Firth of Forth, and through our canal in Mr. Nelson's boat, with the paddle behind; and the results of this voyage have been most satisfactory. The boat, except as regards shape, is replete with errors. She is too heavy, viz. she bears about with her a quantity of iron, sufficient to build nearly two boats of the same size, and of equal strength. Her engine, which ought to have been high pressure, is low pressure, and, though a sweet-going machine, is much too heavy. Her paddle, which, from its position, must necessarily labor under the disadvantage of a deficient surply of water, is so placed as to enjoy this disadvantage to its greatest possible extent, and, in addition, a considerable portion of the broken water, coming from the paddle, strikes on the stern-iron of the boat, and retards her progress. I could state a num-

ber of other faults, but will not trouble you with them. The party most opposed to stern paddles could not have desired a trial, where every possible disadvantage was more decidedly experienced. With all these disadvantages, and taking them to be irremediable, I am decidedly of opinion, that, in all cases where the breadth of a boat is limited, or where the paddles are subjected to risk of damage from narrow banks, &c. stern paddle-boats will be introduced, as best adapted for boats intended to carry large cargoes of goods, at a moderate velocity. If all that is wanted is *despatch*, or *the slow or moderate trackage of vessels* THROUGH A CANAL, the stern paddle may not answer so well as side or centre paddles; but if a boat is wanted which will carry a large cargo, and move, both in a canal, river, or at sea, with a moderate velocity, then the stern paddle is the right means.

"We have already ascertained that the Cyclops can move through the canal with twenty tons of cargo, at a rate of about four miles and a quarter per hour, or rather better; and that, even with this loading, she can drag another vessel behind her, without any considerable diminution of her speed. Every person on board the Cyclops, when the above facts were ascertained, was convinced that an increase of the cargo to thirty-five or forty tons, would not have affected her speed. In fact, it appears as difficult to lessen her speed as to increase it. When her engine makes twenty-five and thirty-three strokes in the minute, her velocity in the canal is about the same; while, without any addition to the number of strokes, her velocity was increased nearly one half when in the Firth of Forth. This clearly shows that the deficiency in speed arises from a defective supply of water.

"But, to return to our experimental voyage: We started from Grangemouth for Alloa, after breakfast on Tuesday the 29th of September. The distance is said to be ten miles, and cannot be under nine miles. We had the tide against us for the first two miles, going out of the Carron river, and for the last mile or so going up to Alloa, and we accomplished the distance in one hour and forty minutes, including a stoppage of some minutes for a small row boat that hailed us. We returned with a favorable tide in the Forth, but strongly against us in the Carron, in an hour and a half. The Cyclops in these two voyages was much by the stern, being without a cargo. We had intended to take in twenty or thirty tons of coal at Alloa, but could not get them. There was a very strong side wind on the Forth, and the Cyclops proved herself a most steady, excellent sea-boat, and steered most beautifully. She appeared to me to steer far better than a side paddle boat, and the men on board said she could turn almost in her own length. When we brought her into the canal, we attached her to the passage boat, and she drew her along the canal two miles—one mile in fourteen, and the other in fifteen minutes. We then detached her from the passage boat, and did two other miles, but could not save, by this decrease of her labor, more than a minute, or a minute and a few seconds in each mile. She was then attached to the passage boat, and dragged her on to Port Dundas. The whole time consumed on the voyage from Alloa to Port Dundas, a distance of forty miles, including the passage of twenty locks, by the Cyclops, and four by the passage boat, a considerable time lost at Grangemouth making some inspections, and several other delays, and a long stop at the entrance of the Union canal, was something under 10 hours and a half; and if the Cyclops had been properly loaded, with a cargo of twenty or thirty tons, the voyage would have been accomplished, in less time, with all the delays and the trackage of the passage boat. The estimate of Mr. Johnstone, who is to have the management of the Cyclops, and myself, is, that with a cargo of from

forty to fifty tons, she will do the voyage to Alloa, even against a head wind, in eight hours and a half, and I do not think this period would be much increased, except by delay at locks, though the Cyclops, in addition, towed another vessel the whole way. I am also much inclined to think that she will make her way against a head wind, much better than a side paddle boat; and that, contrary to the American statement as to stern paddle boats, she will do better than any other kind of steamboat at sea; but this does not bear on the subject of steam-carrier boats intended for sea and canal navigation, as to which I am now writing, where breadth of beam or bearing cannot be attained with side paddles. In canals, stern paddles for goods' boats must be applied, if these boats are intended to go to sea; and, from the experiments already made with the Cyclops, I am certain the application must be successful. I am also convinced that a boat, exactly similar to the Cyclops, may be built, which will carry a larger cargo, and move at a much higher velocity, with the same power. The first improvement is in the use of lighter iron; the second improvement is the substitution of a high pressure for a low pressure engine, and the cutting away all the iron work which obstructs the escape of the broken water. This last alteration would balance the boat a great deal better. The next improvements are by no means so certain or assured as the two last-mentioned, and consist in an alteration of the position of the paddle and of the build behind, so as to obtain a better supply of water for the paddle to act on. To understand these improvements, I beg leave to refer to the accompanying sketch of the Cyclops. From this sketch it will appear that the paddle works in a box supplied with water from the front, sides, and stern of the boat. The supply from the front and sides of the box must come in under the bottom of the boat; and, to facilitate the supply from the front, the centre keel or bottom of the boat is made to ascend a little to the front of the wheel, so as to let the water from the bottom of the boat get easier into the box or tunnel. The water which supplies the wheel, except the portion coming in from the stern, is in a manner pumped up by the wheel from under the bottom of the boat, and there is evidently a constant want of supply, as the water in the inside box is always lower than on the outside. The first improvement, that would suggest itself to any one, would be the removal of the paddle nearer to the stern of the boat, or outer end of the box, so as to make the supply of water from the bottom of the boat more firm, unbroken, and regular, than it can be at that part of the box where the paddle is now situated. To this improvement, it may be objected that such removal would not only make the boat hang more by the stern, but would cause a lengthening of the connecting rod which moves the paddle, and a consequent loss of power. So far as this objection is founded on the additional stern weight, it may be got quit of by the application of a high pressure engine. The weight saved by this application would much more than counterbalance the additional lever power given to the paddle. At all events, if the paddle is not at the end of the box, the *box should end* where the paddle ends, or a small portion of the paddle might even be left out. The next improvement would be the giving of a supply of water to the box and paddles by two large pipes passing angularly from the side of the boat into the front part of the box. This would occasion a certain additional resistance to the progress of the vessel, and the question here to be determined, is, whether this additional resistance would counterbalance the effect of the additional supply of water to the wheel. The last improvement, and which is one that occurred to myself, would be to cut away the two lower sides of the

boxes on each side of the paddle, so as to give a perfectly free admission of the water to the wheel. To this, again, it is objected that you lose a considerable portion of the stern bearing of the boat, and that you also require this bearing, and the strength of the iron cut away to support the paddles. I should think the weight, saved by the high pressure engine, would more than counterbalance the loss of bearing; and, at all events, I think the side boxes might be partially cut away at the bottom and end, so as to allow the supply of water to come more easily and plentifully; and I am rather inclined to think this is the proper improvement, as, by sinking the side boxes in the water a little, they will act as a more effectual protection to the paddles against side wave and wind at sea. All that is wanted for the stern paddle, is to give it an additional supply of water, and, if such additional supply can be obtained, I think these boats will, in time, supersede the use of side paddle boats, even as of passenger boats. In the mean time, I think as goods and luggage boats, more especially where breadth of beam is wanted, and where it would be contracted by the use of side paddles, they are the best. In the case of the Union canal, for instance, where the locks are only twelve feet broad, and where it would be very desirable to have a steam communication direct from Edinburgh to Greenock, this can easily be attained by a stern paddle boat. The boat might be nearly twelve feet beam, and, by building her of lighter iron, and using a high pressure engine, she might be made to carry nearly as much as the Cyclops on the same draught of water. This is also the kind of boat which the Mersey and Irwell Company should get for their goods' trade. She could act as a dragger when required, and would herself do more business than three, four, or five of their lighters.

"I have written to the Union Canal Committee on this subject, and wish them to employ you to prepare for them a plan and specification of a stern paddle boat, and, in the mean time, trouble you with this information."

Since the foregoing letter was written, the Cyclops has been regularly trading between Glasgow and Alloa, and has made her voyages to and from that place, during several of the most stormy days of this winter; leaving Grangemouth on her voyage to Alloa, when no sailing vessel could venture out. She has carried in these voyages a cargo at one time of forty tons, and performs the voyage, from Alloa to Port Dundas, in little more than half the time which is consumed in tracking a vessel of the same burden from Grangemouth to Port Dundas, about two-thirds of the distance. Every person must be struck with the great power of burden of this vessel (the Cyclops) on a small draught of water, and I question much if there be a steamboat in the kingdom which, on a draught of almost double that of the Cyclops, can carry such a cargo. One of the great objections stated by Mr. Grahame to this boat, in his letter to me, is the weight occasioned by the unnecessary thickness of the iron side plates, but this was unavoidable, as the Cyclops was constructed, or rather altered, from an old passage boat belonging to the canal company, where these thick plates were used, and this thickness of plate it was impossible to alter, unless the boat had been entirely rebuilt.

Having been consulted by the Forth and Clyde Canal Company, as to the improvements suggested by Mr. Grahame on the Cyclops, I have inspected her, and made a voyage with her to Alloa. After due consideration, I am convinced that all the objections to the build of the Cyclops may be got over, and that, by a change in the position of the paddle, a much greater improve-

ment may be made in the powers and capabilities of stern paddle vessels, than is at present anticipated.

The improvements I suggest, would be, to construct a vessel with two narrow paddles on each side, close to the rudder or stern of the vessel. This would, in a great measure, obviate the objections urged against the Cyclops; it would remove every impediment to the free access of the water to the paddles, and allow a free and open outlet to the discharge of the wheels on each side: it would also give considerably more bearing to the stern of the vessel; facilitate the working of the rudder; and furnish a large useful hold, instead of two comparatively small ones. It may here be urged, that two paddle wheels, viz., one on each side at the stern, would be liable to get damaged against the locks, bridges, and banks of the canal: this is certainly an objection of some weight, but, on a minute inspection of the plan, it will be found that a remedy is provided by a fender, or Portcullis, sliding down on the outside of the wheels, to protect them from injury during the time they are passing the canal: at other times, when the vessel is in the open sea, the Portcullis is drawn up, leaving the whole space open for the free action of the paddles.

I am quite persuaded that this change will tend to assimilate, as much as possible, the navigation of the sea, rivers, and canals, and will have no effect on the surge occasioned by the motion of the vessel through the water: in fact, I am rather inclined to think it will have a tendency to neutralize the surge, and produce no other agitation than a rippling wave in the centre of the canal. I think the change must also greatly improve the speed of the vessel, but, to what amount, it is impossible to say without trial. A plan of the new proposed steamer is annexed to this publication with the other plates.

It may be asked whether steam navigation is applicable to, or would pay on canals not communicating with the sea. The experiment of the Cyclops has completely proved the benefit of steam navigation in a canal connected with a firth or arm of the sea. In this case, greater speed is acquired, both in the canal and at sea, than could be got by any other kind of boat, and, in addition, perfect regularity is insured after the steamer leaves the canal; or, in short, the firth, or arm of the sea connected with the canal, and even the sea itself, are turned into a portion of inland navigation, so far as respects regularity.

In a canal, however, not communicating with the sea, steam-power must be equally efficacious, although, in its general application, it may not be productive of the same advantages as on those canals having a free outlet to the sea; as. in the latter instance, vessels have the opportunity of extending their voyages to the adjoining ports on the coast.

However much I was persuaded that steam power was the cheapest for high velocities, and also for propelling vessels on canals where the trade was regular, I was not, till lately, prepared to consider a steamboat on a canal as the cheapest for the conveyance of goods where the trade was irregular, and where the boat had not only to contain a cargo, but, at the same time, had to carry her own engine, and all the conveniencies necessary for the application of machinery.

Mr. Grahame has lately put into my hands a letter on this subject, addressed to a shipping company, carrying goods along a line of canal fifty six miles in length: the calculations contained in that communication are given in the appendix, and seem to be decisive in favor of steam power.

The company to which this letter is addressed, have to pay for a quantity of horse power sufficient to deliver forty tons of goods at each extremity of the line of fifty-six miles every day in the year, besides a spare power employed chiefly in one particular branch of their trade. The sum they pay for each delivery is one guinea each way, *or at a rate of about one-ninth of a penny per ton per mile for the trackage of the goods conveyed.* The company in question supply the trackling lines, but, with this addition, the charge for trackage is not increased to *one-eigth of a penny per ton per mile.*

This is certainly a small sum whereon to effect a saving by a change of power; but, nevertheless, it appears (from Mr. Grahame's and my own calculations) that not only such saving may be effected, but an additional saving of a large portion of time can be made, by the change from horse to steam-power. Having said this much, I will refer the reader to the calculations printed in the appendix, in order that he may draw his own conclusions as to the accuracy of those statements.

The calculations here referred to make it quite unnecessary to say any thing on the subject of steam power as a substitute for trackage on canals. If it be so much cheaper than horses in the expensive shape of a moving and carrying power, united in the same boat, what advantages may not all canals derive from its introduction in the cheap form of a tug-boat in place of horses?

I should here observe, that the application of steam, either as a propelling or tracking power on canals, will, on most navigations, require a regular system of management. Certainty and despatch are the very sinews of commerce. Every facility should, therefore, be given to the arrival and departure of vessels, to insure the confidence of traders, and perfect certainty that goods will be received and delivered at their respective destinations, at proper and stated intervals. I conceive this to be a principle of management imperative on canal and all other companies, as nothing conduces more to the well-being of trading establishments than good regulations, founded on celerity and despatch in the traffic.

Errata.

Page 155, line 6 from top, for 150 read 1500.
" 173, line 10 from top, strike out the word *not*, so as to read "are no doubt the true ones why."
" 216, line 7 from top, for 30 read 300.